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# AWS Cloud Development Kit (AWS CDK) v1

## Developer Guide

### Version 1

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# **AWS Cloud Development Kit (AWS CDK) v1: Developer Guide**

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## Table of Contents

What is the AWS CDK? .....	1
Why use the AWS CDK? .....	2
Developing with the AWS CDK .....	6
The Construct Programming Model .....	6
Additional documentation and resources .....	6
Resources for serverless apps with CDK .....	7
Contributing to the AWS CDK .....	7
About Amazon Web Services .....	7
Getting started .....	8
Your background .....	8
Key concepts .....	8
Supported programming languages .....	9
Prerequisites .....	10
Install the AWS CDK .....	12
Bootstrapping .....	12
AWS CDK tools .....	13
Next steps .....	13
Your first AWS CDK app .....	13
Create the app .....	14
Build the app .....	15
List the stacks in the app .....	16
Add an Amazon S3 bucket .....	16
Synthesize an AWS CloudFormation template .....	19
Deploying the stack .....	19
Modifying the app .....	20
Destroying the app's resources .....	24
Next steps .....	24
Working with the AWS CDK .....	25
AWS CDK prerequisites .....	25
Language-specific prerequisites .....	26
AWS Construct Library .....	26
Interfaces vs. construct classes .....	26
In TypeScript .....	27
Prerequisites .....	27
Creating a project .....	28
Using local tsc and cdk .....	28
Managing AWS Construct Library modules .....	29
AWS CDK idioms in TypeScript .....	30
Building, synthesizing, and deploying .....	30
In JavaScript .....	31
Prerequisites .....	31
Creating a project .....	31
Using local cdk .....	28
Managing AWS Construct Library modules .....	32
AWS CDK idioms in JavaScript .....	33
Synthesizing and deploying .....	34
Using TypeScript examples with JavaScript .....	35
Migrating to TypeScript .....	37
In Python .....	37
Prerequisites .....	38
Creating a project .....	38
Managing AWS Construct Library modules .....	39
AWS CDK idioms in Python .....	40
Synthesizing and deploying .....	42

In Java .....	43
Prerequisites .....	43
Creating a project .....	44
Managing AWS Construct Library modules .....	44
AWS CDK idioms in Java .....	45
Building, synthesizing, and deploying .....	46
In C# .....	47
Prerequisites .....	47
Creating a project .....	47
Managing AWS Construct Library modules .....	48
AWS CDK idioms in C# .....	50
Building, synthesizing, and deploying .....	51
In Go .....	52
Prerequisites .....	52
Creating a project .....	52
Managing AWS Construct Library modules .....	53
AWS CDK idioms in Go .....	53
Building, synthesizing, and deploying .....	55
Managing dependencies .....	56
TypeScript and JavaScript .....	56
Applications .....	56
Construct libraries .....	57
Installing and updating dependencies .....	58
Python .....	58
Applications .....	59
Construct libraries .....	59
Java .....	60
C# .....	61
Editing the project file directly .....	61
The Visual Studio NuGet GUI .....	61
The NuGet console .....	62
The dotnet command .....	62
The nuget command .....	63
Go .....	63
Migrating to AWS CDK v2 .....	64
CDK Toolkit v2 compatibility .....	64
Translating from TypeScript .....	65
Importing a module .....	65
Instantiating a construct .....	67
Accessing members .....	68
Enum constants .....	69
Object interfaces .....	69
Concepts .....	71
Constructs .....	71
AWS Construct library .....	71
Composition .....	72
Initialization .....	72
Apps and stacks .....	72
Using L1 constructs .....	75
Using L2 constructs .....	77
Configuration .....	78
Interacting with constructs .....	79
Writing your own constructs .....	81
The construct tree .....	86
Apps .....	87
The app construct .....	88
App lifecycle .....	89

Cloud assemblies .....	90
Stacks .....	91
Stack API .....	97
Nested stacks .....	97
Environments .....	98
Resources .....	104
Resource attributes .....	105
Referencing resources .....	106
Referencing resources in a different stack .....	107
Referencing resources in your AWS account .....	109
Physical names .....	112
Passing unique identifiers .....	113
Permission grants .....	115
Metrics and alarms .....	116
Network traffic .....	118
Event handling .....	120
Removal policies .....	121
Identifiers .....	124
Construct IDs .....	124
Paths .....	126
Unique IDs .....	127
Logical IDs .....	128
Tokens .....	128
Tokens and token encodings .....	129
String-encoded tokens .....	130
List-encoded tokens .....	132
Number-encoded tokens .....	132
Lazy values .....	132
Converting to JSON .....	134
Parameters .....	134
Defining parameters .....	135
Using parameters .....	136
Deploying with parameters .....	138
Tagging .....	138
Tag priorities .....	139
Optional properties .....	140
Example .....	142
Tagging single constructs .....	144
Assets .....	146
Assets in detail .....	146
Asset types .....	146
AWS CloudFormation resource metadata .....	159
Permissions .....	159
Principals .....	159
Grants .....	160
Roles .....	161
Resource policies .....	166
Using external IAM objects .....	167
Context .....	167
Sources of context values .....	168
Context methods .....	169
Viewing and managing context .....	169
AWS CDK Toolkit --context flag .....	170
Example .....	170
Feature flags .....	173
Aspects .....	174
Aspects in detail .....	174

Example .....	175
Bootstrapping .....	177
How to bootstrap .....	178
Bootstrapping templates .....	179
Customizing bootstrapping .....	181
Stack synthesizers .....	182
Customizing synthesis .....	184
The bootstrapping template contract .....	189
Abstractions and escape hatches .....	192
Using AWS CloudFormation constructs directly .....	193
Modifying the AWS CloudFormation resource behind AWS constructs .....	195
Raw overrides .....	197
Custom resources .....	199
Best practices .....	200
Organization best practices .....	202
Coding best practices .....	202
Start simple and add complexity only when you need it .....	203
Align with the AWS Well-Architected framework .....	203
Every application starts with a single package in a single repository .....	203
Move code into repositories based on code lifecycle or team ownership .....	204
Infrastructure and runtime code live in the same package .....	204
Construct best practices .....	204
Model with constructs, deploy with stacks .....	204
Configure with properties and methods, not environment variables .....	205
Unit test your infrastructure .....	205
Don't change the logical ID of stateful resources .....	205
Constructs aren't enough for compliance .....	205
Application best practices .....	206
Make decisions at synthesis time .....	206
Use generated resource names, not physical names .....	206
Define removal policies and log retention .....	207
Separate your application into multiple stacks as dictated by deployment requirements .....	207
Commit <code>cdk.context.json</code> to avoid non-deterministic behavior .....	207
Let the AWS CDK manage roles and security groups .....	208
Model all production stages in code .....	208
Measure everything .....	209
API reference .....	210
Versioning .....	210
AWS CDK Toolkit (CLI) compatibility .....	210
AWS CDK stability index .....	211
Language binding stability .....	211
Examples .....	213
Serverless .....	213
Create an AWS CDK app .....	213
Create a Lambda function to list all widgets .....	215
Create a widget service .....	216
Add the service to the app .....	221
Deploy and test the app .....	222
Add the individual widget functions .....	222
Clean up .....	226
ECS .....	226
Creating the directory and initializing the AWS CDK .....	227
Add the Amazon EC2 and Amazon ECS packages .....	228
Create a Fargate service .....	229
Clean up .....	232
AWS CDK examples .....	232
How tos .....	233

Get environment value .....	233
Get CloudFormation value .....	234
Import or migrate CloudFormation template .....	234
Install the cloudformation-include module .....	234
Importing a template .....	235
Accessing imported resources .....	238
Replacing parameters .....	240
Other template elements .....	241
Nested stacks .....	242
Use resources from the CloudFormation Public Registry .....	244
Activating a third-party resource in your account and region .....	244
Adding a resource from the AWS CloudFormation Public Registry to your CDK app .....	246
Get SSM value .....	247
Reading Systems Manager values at deployment time .....	247
Reading Systems Manager values at synthesis time .....	248
Writing values to Systems Manager .....	249
Get Secrets Manager value .....	250
Create an app with multiple stacks .....	252
Before you begin .....	252
Add optional parameter .....	253
Define the stack class .....	255
Create two stack instances .....	258
Synthesize and deploy the stack .....	260
Clean up .....	261
Set CloudWatch alarm .....	261
Using an existing metric .....	261
Creating your own metric .....	262
Creating the alarm .....	263
Get context value .....	265
Create CDK Pipeline .....	266
Bootstrap your AWS environments .....	266
Initialize project .....	268
Define a pipeline .....	270
Application stages .....	274
Testing deployments .....	282
Security notes .....	288
Troubleshooting .....	288
Tools .....	290
AWS CDK Toolkit .....	290
Toolkit commands .....	290
Specifying options and their values .....	291
Built-in help .....	292
Version reporting .....	292
Specifying credentials and region .....	293
Specifying the app command .....	294
Specifying stacks .....	295
Bootstrapping your AWS environment .....	296
Creating a new app .....	296
Listing stacks .....	297
Synthesizing stacks .....	297
Deploying stacks .....	298
Comparing stacks .....	301
Configuration (cdk.json) .....	302
Toolkit reference .....	304
AWS Toolkit for VS Code .....	311
AWS SAM integration .....	311
Testing constructs .....	312

Getting started .....	312
The example stack .....	315
The Lambda function .....	320
Running tests .....	321
Fine-grained assertions .....	321
Matchers .....	325
Capturing .....	330
Snapshot tests .....	332
Tips for tests .....	336
Security .....	337
Identity and access management .....	337
Compliance validation .....	338
Resilience .....	338
Infrastructure security .....	339
Troubleshooting .....	340
OpenPGP keys .....	348
Current keys .....	348
AWS CDK OpenPGP key .....	348
jsii OpenPGP key .....	349
Historical keys .....	349
AWS CDK OpenPGP key (2022-04-07) .....	350
jsii OpenPGP key (2022-04-07) .....	351
AWS CDK OpenPGP key (2018-06-19) .....	351
jsii OpenPGP key (2018-08-06) .....	352
Document history .....	354



# 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.

## Important

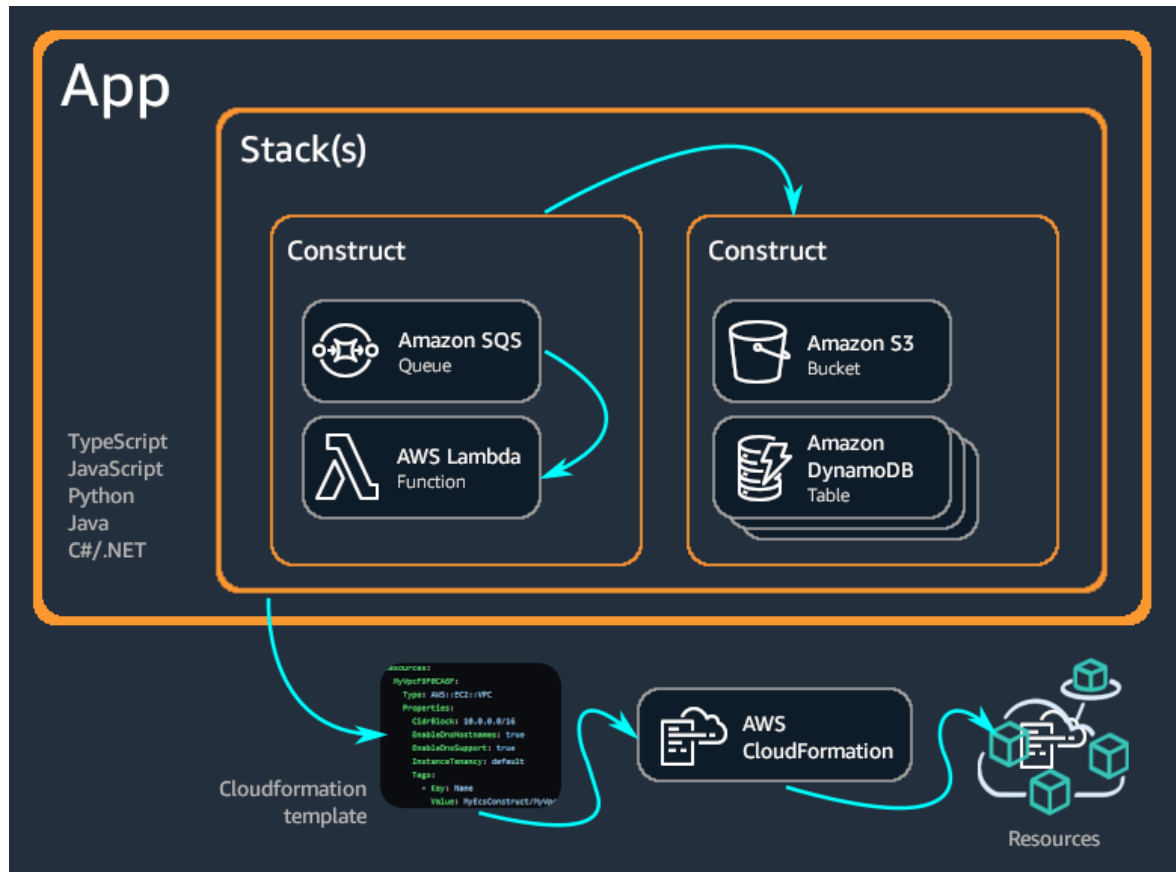
The CDK has been released in two major versions, v1 and v2. This is the Developer Guide for the older AWS CDK v1.

CDK v1 entered maintenance on June 1, 2022. During the maintenance phase, CDK v1 will receive critical bug fixes and security patches only. New features will be developed exclusively for CDK v2 during the v1 maintenance phase. On June 1, 2023, support will end for AWS CDK v1. For more details, see [AWS CDK Maintenance Policy](#).

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 \(p. 71\)](#). You compose these together into [Stacks \(p. 91\)](#) and [Apps \(p. 87\)](#).



## 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" \(p. 226\)](#)).

TypeScript

```
export class MyEcsConstructStack extends core.Stack {
  constructor(scope: core.App, id: string, props?: core.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 core.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(core.Stack):

    def __init__(self, scope: core.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,
            });
    }
}
```

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 cdk-workshop-stack.ts •
lib > TS cdk-workshop-stack.ts > CdkWorkshopStack > constructor > hello > runtime
1 import * as cdk from '@aws-cdk/core';
2 import * as lambda from '@aws-cdk/aws-lambda';
3 import * as apigw from '@aws-cdk/aws-apigateway';
4 import { HitCounter } from './hitcounter';
5 import { TableViewer } from 'cdk-dynamo-table-viewer';
6
7 export class CdkWorkshopStack extends cdk.Stack {
8   constructor(scope: cdk.App, id: string, props?: cdk.StackProps) {
9     super(scope, id, props);
10
11     const hello = new lambda.Function(this, 'HelloHandler', {
12       runtime: lambda.Runtime.NODEJS_10_X,
13       code: lambda.Code.asset('code'),
14       handler: 'hello.handler',
15     });
16
17     const HelloWorldWithCounter = new lambda.Function(this, 'HelloWithCounter', {
18       runtime: lambda.Runtime.NODEJS_10_X,
19       code: lambda.Code.asset('code'),
20       handler: 'hello.handler',
21     });
22
23     new apigw.LambdaRestApi(this, 'Api', {
24       handler: HelloWorldWithCounter,
25     });
26
27     new TableViewer(this, 'ViewHitCounter', {
28       title: 'Hello Hits',
29       table: HelloWorldWithCounter.table,
30     });
31   }
}
```

## Developing with the AWS CDK

It's easy to [get set up \(p. 8\)](#) and [write your first CDK app \(p. 13\)](#). 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 \(p. 290\)](#) is a command line tool for interacting with CDK apps. It enables developers to synthesize artifacts such as AWS CloudFormation templates, deploy stacks to development AWS accounts, and **diff** against a deployed stack to understand the impact of a code change.

The [AWS Construct Library \(p. 71\)](#) 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](#), such as 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 \(p. 348\)](#)
  - [jsii OpenPGP key \(p. 349\)](#)
- [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 which 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 \(p. 13\)](#).

## 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 Identity and Access Management \(IAM\)](#). You might already have AWS credentials on your workstation for use with an AWS SDK or the AWS CLI and experience working with AWS resources programmatically.

Familiarity with [AWS CloudFormation](#) is also useful, as 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 \(p. 87\)](#) 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 \(p. 91\)](#). Stacks (equivalent to AWS CloudFormation stacks) contain [constructs \(p. 71\)](#), each of which defines one or more concrete AWS resources, such as Amazon S3 buckets, Lambda functions, Amazon DynamoDB tables, and so on.

Constructs (as well as 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 AWS 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 convert one or more AWS CDK stacks to AWS CloudFormation templates and related assets (a process called *synthesis*) and to deploy your stacks to an AWS account.

The AWS CDK includes a library of AWS constructs called the AWS Construct Library. Each AWS service has at least one corresponding module in the library containing the constructs that represent that service's resources.

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, so 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, in the Amazon S3 module, CfnBucket is the L1 construct for an Amazon S3 bucket.

- **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, in the Amazon S3 module, Bucket is the L2 construct for an Amazon S3 bucket.

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

- **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. In the AWS Construct Library, patterns are in separate modules from L1 and L2 constructs.

The AWS CDK's core module (usually imported into code as `core` or `cdk`) contains constructs used by the AWS CDK itself as well as base classes for apps, stacks, and other AWS CDK objects.

Numerous third parties have also published constructs compatible with the AWS CDK. Visit [Construct Hub](#) to explore the AWS CDK construct 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, but 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) and 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, so writing AWS CDK apps feels natural, not like writing TypeScript in Python (for example). Take a look:

### 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"  
    }  
});
```

#### 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 topics that explain how to use the AWS CDK in all supported languages.

- [the section called "In TypeScript" \(p. 27\)](#)
- [the section called "In JavaScript" \(p. 31\)](#)
- [the section called "In Python" \(p. 37\)](#)
- [the section called "In Java" \(p. 43\)](#)
- [the section called "In C#" \(p. 47\)](#)

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. See [Translating from TypeScript \(p. 65\)](#).

## Prerequisites

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

All AWS CDK developers, even those working in Python, Java, C#, or Go, need [Node.js](#) 10.13.0 or later. All supported languages use the same back end, which runs on Node.js. We recommend a version in [active long-term support](#), which, at this writing, is the latest 16.x release. 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.

You must configure your workstation with your credentials and an AWS region, if you have not already done so. If you have the AWS CLI installed, the easiest way to satisfy this requirement is issue the following command:

```
aws configure
```

Provide your AWS access key ID, secret access key, and default region when prompted.

You may also manually create or edit the `~/.aws/config` and `~/.aws/credentials` (macOS/Linux) or `%USERPROFILE%\aws\config` and `%USERPROFILE%\aws\credentials` (Windows) files to contain credentials and a default region, in the following format.

- In `~/.aws/config` or `%USERPROFILE%\aws\config`

```
[default]
region=us-west-2
```

- In `~/.aws/credentials` or `%USERPROFILE%\aws\credentials`

```
[default]
aws_access_key_id=AKIAI44QH8DHBEXAMPLE
aws_secret_access_key=je7MtGbClwBF/2Zp9Utk/h3yCo8nvbEXAMPLEKEY
```

### Note

Although the AWS CDK uses credentials from the same configuration files as other AWS tools and SDKs, including the [AWS Command Line Interface](#), it may behave slightly differently from these tools. In particular, if you use a named profile from the `credentials` file, the `config` must have a profile of the same name specifying the region. The AWS CDK does not fall back to reading the region from the `[default]` section in `config`. Also, do not use a profile named "default" (e.g. `[profile default]`). See [Setting credentials](#) for complete details on setting up credentials for the AWS SDK for JavaScript, which the AWS CDK uses under the hood.

The AWS CDK natively supports AWS IAM Identity Center (successor to AWS Single Sign-On). To use IAM Identity Center with the CDK, first create a profile using **aws configure sso**. Then log in using **aws sso login**. Finally, specify this profile when issuing **cdk** commands using the **--profile** option or the `AWS_PROFILE` environment variable.

Alternatively, you can set the environment variables `AWS_ACCESS_KEY_ID`, `AWS_SECRET_ACCESS_KEY`, and `AWS_DEFAULT_REGION` to appropriate values.

### Important

We strongly recommend against using your AWS root account for day-to-day tasks. Instead, create a user in IAM and use its credentials with the CDK. Best practices are to change this account's access key regularly and to use a least-privileges role (specifying `--role-arn`) when deploying.

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 3.6 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 Developer Guide). IDE must be able to import Maven projects. Check to make sure 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.

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

### 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.

## Install the AWS CDK

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

```
npm install -g aws-cdk@1.x
```

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

```
cdk --version
```

## Bootstrapping

Many AWS CDK stacks that you write will include [assets](#) (p. 146): external files that are deployed with the stack, such as AWS Lambda functions or Docker images. The AWS CDK uploads these to an Amazon S3 bucket or other container so they are available to AWS CloudFormation during deployment. Deployment requires that these containers already exist in the account and region you are deploying into. Creating them is called [bootstrapping](#) (p. 177). 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 have created named profiles in your local AWS configuration, you can use the `--profile` option to display the account information for a specific profile's account, such as the *prod* profile as shown here.

```
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” \(p. 290\)](#).

The [AWS Toolkit for Visual Studio Code](#) is an open-source plug-in 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, including 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 \(p. 13\)](#).
- 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 as well as from AWS.
- Dig deeper into concepts like [the section called “Environments” \(p. 98\)](#), [the section called “Assets” \(p. 146\)](#), [the section called “Bootstrapping” \(p. 177\)](#), [the section called “Permissions” \(p. 159\)](#), [the section called “Context” \(p. 167\)](#), [the section called “Parameters” \(p. 134\)](#), and [Abstractions and escape hatches \(p. 192\)](#).
- 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 \(p. 8\)](#) 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.

### Note

This tutorial does not currently include instructions or code examples for Go.

In this tutorial, you'll learn about the structure of a AWS CDK project, how to use the AWS Construct Library to define AWS resources using code, and 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 the workflow you're already familiar with as a developer, just with 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. Build the app (optional; the AWS CDK Toolkit will do it 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, so if you use a different name, the code in this tutorial won't work.

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

Now initialize the app using the **cdk init** command, specifying the desired template ("app") and programming language. That is:

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 to 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.

#### Tip

If you don't specify a template, the default is "app," which is the one we wanted anyway, so technically you can leave it out 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 making changes to your code, you'd build (compile) it. This isn't strictly necessary with the AWS CDK—the Toolkit does it for you so 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

### Note

If your project was created with an older version of the AWS CDK Toolkit, it may not automatically build when you run it. If changes you make in your code fail to be reflected in the synthesized template, try a manual build. Make sure you are using the latest available version of the AWS CDK for this tutorial.

## List the stacks in the app

Just to verify 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" \(p. 14\)](#) 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.

Install the Amazon S3 package from the AWS Construct Library.

### TypeScript

```
npm install @aws-cdk/aws-s3
```

### JavaScript

```
npm install @aws-cdk/aws-s3
```

### Python

```
pip install aws-cdk.aws-s3
```

### Java

Add the following to the `<dependencies>` container of `pom.xml`.

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>s3</artifactId>
  <version>${cdk.version}</version>
</dependency>
```

### Tip

If you are using a Java IDE, it probably has a simpler way to add this dependency to your project, such as a GUI for editing the POM. We recommend editing `pom.xml` by hand because of the use of the `cdk.version` variable, which helps keep the versions of installed modules consistent.

### C#

Run the following command in the `src/HelloCdk` directory.

```
dotnet add package Amazon.CDK.AWS.S3
```



Or **Tools > NuGet Package Manager > Manage NuGet Packages for Solution** in Visual Studio, then locate and install the `Amazon.CDK.AWS.S3` package

Next, 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/core';
import * as s3 from '@aws-cdk/aws-s3';

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/core');
const s3 = require('@aws-cdk/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

Add the following import statement in `hello_cdk/hello_cdk_stack.py` in the `hello_cdk` directory below the existing imports.

```
from aws_cdk import aws_s3 as s3
```

Replace the comment with the following code.

```
bucket = s3.Bucket(self,
    "MyFirstBucket",
    versioned=True,)
```

#### Java

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

```
package com.myorg;
```

```
import software.amazon.awscdk.core.*;
import software.amazon.awscdk.services.s3.Bucket;

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#

In src/HelloCdk/HelloCdkStack.cs:

```
using Amazon.CDK;
using Amazon.CDK.AWS.S3;

namespace HelloCdk
{
    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
            });
        }
    }
}
```

Bucket is the first construct 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 so the AWS CDK can update it if you change how it's defined in your app. Here it is "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 just 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. Two, actually; 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(s) 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; the beginning of our app's output is shown below. 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 very familiar with AWS CloudFormation, you should be able to find the definition for the bucket 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 we can continue to improve it. For details, including how to opt out of version reporting, see [Version reporting \(p. 292\)](#).

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 our bucket so it can be automatically deleted when we delete the stack, which involves changing its `RemovalPolicy`. Also, because AWS CloudFormation won't delete Amazon S3 buckets that contain any objects, we'll ask the AWS CDK to delete the objects from our bucket before destroying the bucket, via the `autoDeleteObjects` property.

### 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=core.RemovalPolicy.DESTROY,
    auto_delete_objects=True)
```

### Java

Update `src/main/java/com/myorg/HelloCdkStack.java`, adding the new import and updating the bucket definition in the appropriate places.

```
import software.amazon.awscdk.core.RemovalPolicy;
```

```
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
});
```

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 and deploys a changeset 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` and compares it 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 aforementioned 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 because the AWS CDK default is to retain the bucket when the stack is deleted, while AWS CloudFormation's default is to delete it. See [the section called “Removal policies” \(p. 121\)](#) for further details.

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

### Important

Since the `autoDeleteObjects` property is implemented using an AWS CloudFormation custom resource, which is implemented using an AWS Lambda function, our stack contains an [asset](#) (p. 146). This fact requires that our AWS account and region be [bootstrapped](#) (p. 177) so that there's an Amazon S3 bucket to hold the asset during deployment. If you haven't already bootstrapped, issue:

```
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 hadn't changed 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" \(p. 98\)](#), [the section called "Assets" \(p. 146\)](#), [the section called "Permissions" \(p. 159\)](#), [the section called "Context" \(p. 167\)](#), [the section called "Parameters" \(p. 134\)](#), and [Abstractions and escape hatches \(p. 192\)](#).
- 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" \(p. 52\)](#).

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](https://nodejs.org). We recommend the [active LTS version](#) (at this writing, the latest 16.x release). 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 as well as 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” \(p. 27\)](#)
- [the section called “In JavaScript” \(p. 31\)](#)
- [the section called “In Python” \(p. 37\)](#)
- [the section called “In Java” \(p. 43\)](#)
- [the section called “In C#” \(p. 47\)](#)
- [the section called “In Go” \(p. 52\)](#)

### 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 construct modules organized by AWS service. 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 imported 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 importing resources defined outside CDK applications using methods such as `Bucket.fromBucketArn()`. Imported 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 imported 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 imported 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 (shown in the AWS CDK API Reference as Structs) that are associated with specific constructs. For example, `IBucketProps` is the smallest set of properties required to instantiate a bucket. Such interfaces can be useful when subclassing constructs 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 such as `BucketProps`.

**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 \(p. 25\)](#).

You also need TypeScript itself (version 2.7 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 [core](#) 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@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=npk 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.

The AWS CDK core module is named `@aws-cdk/core`. AWS Construct Library modules are named like `@aws-cdk/SERVICE-NAME`. 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 modules for Amazon S3 and AWS Lambda.

```
npm install @aws-cdk/aws-s3 @aws-cdk/aws-lambda
```

Some services' Construct Library support is in more than one module. For example, besides the `@aws-cdk/aws-route53` module, there are three additional Amazon Route 53 modules, named `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/core`.

```
import { App, Construct } from '@aws-cdk/core';
```

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

```
import * as cdk from '@aws-cdk/core';
```

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

```
import * as s3 from '@aws-cdk/aws-s3';
```

### Important

All AWS Construct Library modules used in your project must be the same version.

## 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*, 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/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. Recent versions of the language include 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. 91) 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" \(p. 290\)](#).

## 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 \(p. 25\)](#).

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 [core](#) 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.



The AWS CDK core module is named `@aws-cdk/core`. AWS Construct Library modules are named like `@aws-cdk/SERVICE-NAME`. 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 modules for Amazon S3 and AWS Lambda.

```
npm install @aws-cdk/aws-s3 @aws-cdk/aws-lambda
```

Some services' Construct Library support is in more than one module. For example, besides the `@aws-cdk/aws-route53` module, there are three additional Amazon Route 53 modules, named `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/core`.

```
const { App, Construct } = require('@aws-cdk/core');
```

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

```
const cdk = require('@aws-cdk/core');
```

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

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

### Important

All AWS Construct Library modules used in your project must be the same version.

## 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. 91) 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” \(p. 290\)](#).

## 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, 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/core';
import { Bucket, BucketPolicy } from '@aws-cdk/aws-s3';
```

JavaScript

```
const cdk = require('@aws-cdk/core');
const { Bucket, BucketPolicy } = require('@aws-cdk/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 core.Stack {  
  bucket: s3.Bucket;  
  // ...  
}  
  
function makeEnv(account: string, region: string) : object {  
  // ...  
}
```

## JavaScript

```
var encrypted = true;  
  
class myStack extends core.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](#). Socrase won't complain if code uses an undefined variable, for example, as `tsc` would. If it is syntactically valid, then with few exceptions, Socrase 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](https://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 \(p. 25\)](#).

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](https://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.

After initializing the project, activate the project's 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`.

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

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

#### 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).

## 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
```

The AWS CDK core module is named `aws-cdk.core`. AWS Construct Library modules are named like `aws-cdk.SERVICE-NAME`. 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 modules for Amazon S3 and AWS Lambda.

```
python -m pip install aws-cdk.aws-s3 aws-cdk.aws-lambda
```

Some services' Construct Library support is in more than one module. For example, besides the `aws-cdk.aws-route53` module, there are three additional Amazon Route 53 modules, 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 are similar to their package names. Simply replace the hyphens with underscores.

```
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 `aws_cdk.core`.

```
from aws_cdk.core import App, Construct
```

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

```
import aws_cdk.core 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 modules. This strategy makes updating your dependencies simpler. Here is what your `requirements.txt` file might look like if you have installed the Amazon S3 and AWS Lambda modules as shown earlier.

```
aws-cdk.aws-s3==X.YY.ZZ
aws-cdk.aws-lambda==X.YY.ZZ
```

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
```

### **Important**

All AWS Construct Library modules used in your project must be the same version.

## 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.core 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 (CfnXXXXX) construct to an L2 or L3 construct, or vice versa.

The AWS CDK Python modules 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 \(p. 91\)](#) 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” \(p. 290\)](#).

## 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 modules comprising the AWS Construct Library are distributed via the [Maven Central Repository](#).

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 \(p. 25\)](#).

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.core` 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` and named with a short version (no AWS or Amazon prefix) of their service's name. For example, the Maven artifact ID for Amazon S3 is `s3`. [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 module. For example, Amazon Route 53 has the three modules in addition to the main `software.amazon.awscdk.route53` module, named `route53-patterns`, `route53resolver`, and `route53-targets`.

The AWS CDK's core module, which you'll need in most AWS CDK apps, is imported in Java code as `software.amazon.awscdk.core`. 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.

**Important**

All AWS Construct Library modules used in your project must be the same version.

Specify the modules that your application depends on by editing `pom.xml` and adding a new `<dependency>` element in the `<dependencies>` container. For example, the following `<dependency>` element specifies the Amazon S3 construct library module:

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>s3</artifactId>
  <version>${cdk.version}</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.

The default `pom.xml` defines the variable `cdk.version` to be the version of the AWS CDK that created the project. You can easily update the version required by updating the value of this variable, which keeps all AWS Construct Library module versions in sync.

```
<cdk.version>1.XX.Y</cdk.version>
```

This value can be any valid Maven version specifier. For example, `[1.XX.Y, 2.0)` indicates that any version between the current version 1.XX.Y (inclusive) and 2.0 (exclusive), may be installed. However, to avoid mismatched versions, we recommend using a fixed version like 1.XX and updating it when moving a new AWS CDK release.

## 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 \(p. 91\)](#) 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” \(p. 290\)](#).

## 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 \(p. 25\)](#).

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 NuGet package. It and its dependencies are installed automatically by NuGet.

## Managing AWS Construct Library modules

The .NET ecosystem uses the NuGet package manager. AWS Construct Library modules are named like Amazon .CDK .AWS .*SERVICE-NAME* where the service name is a short name without an AWS or Amazon prefix. For example, the NuGet package name for the Amazon S3 module is Amazon .CDK .AWS .S3. If you can't find a package you want, [search Nuget.org](https://www.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, Amazon Route 53 has the three modules in addition to the main Amazon .CDK .AWS .Route53 module, named Route53 .Patterns, Route53 .Resolver, and Route53 .Targets.

The AWS CDK's core 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 and are named the same as their NuGet package name. For example, the Amazon S3 module's namespace is Amazon .CDK .AWS .S3.

We recommend writing a single C# `using` directive for each AWS Construct Library module 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.

### Important

All AWS Construct Library modules used in your project must be the same version.

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](#).

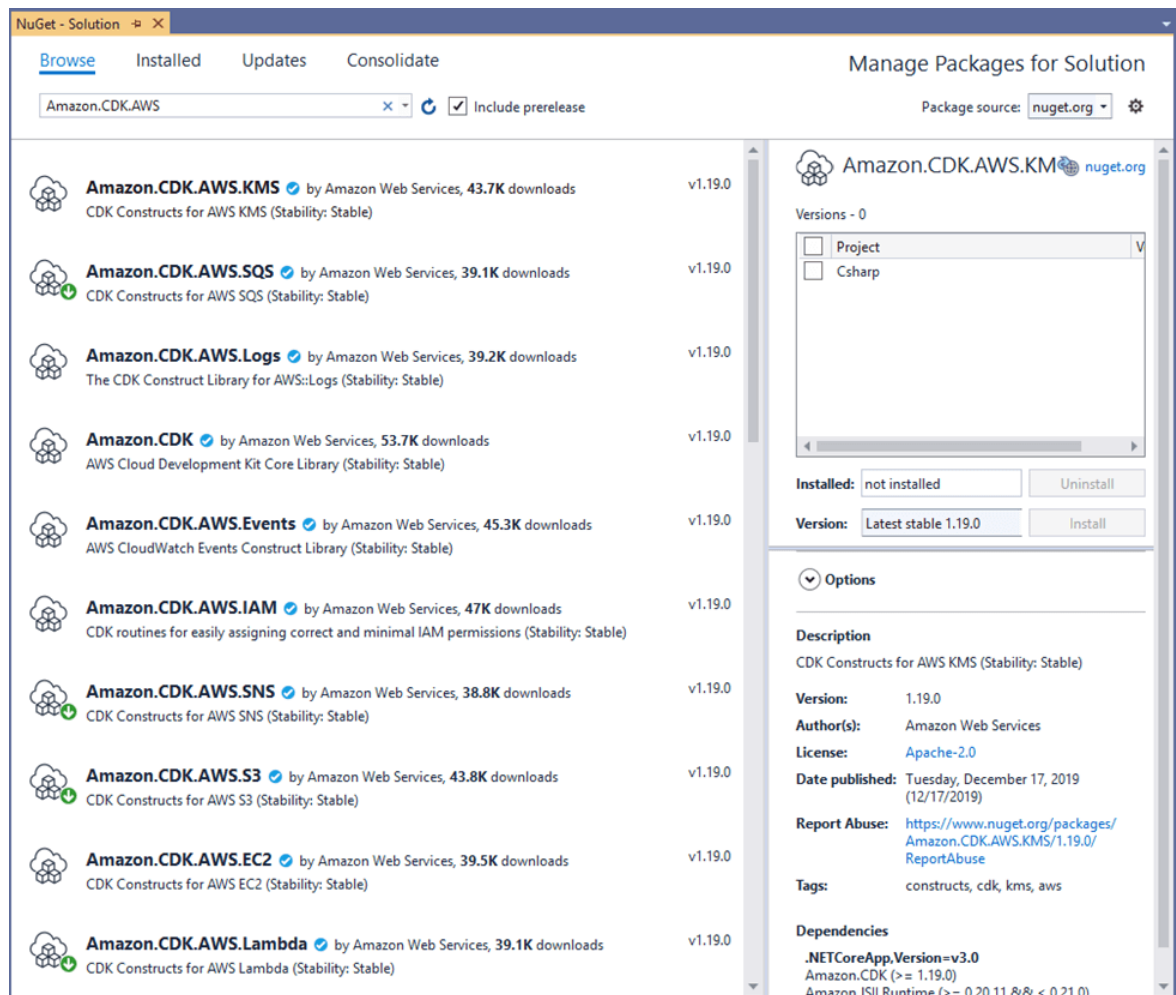
## The Visual Studio NuGet GUI

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 (mark the **Include prerelease** checkbox) and add them to any of the open projects.

### Note

All AWS Construct Library modules deemed "experimental" (see [the section called "Versioning" \(p. 210\)](#)) are flagged as pre-release in NuGet.





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.

```
dotnet add package Amazon.CDK.AWS.S3
```

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.S3
```

To install a specific version of a package, include the `-v` flag and the desired version. AWS Construct Library modules that are deemed "experimental" (see [the section called "Versioning" \(p. 210\)](#)) are flagged as pre-release in NuGet, and must be installed using an explicit version number.

```
dotnet add package Amazon.CDK.AWS.S3 -v VERSION-NUMBER
```

To update a package, issue the same `dotnet add` command you used to install it. If you do not specify a version number, the latest version is installed. 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[]` 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 \(p. 91\)](#) 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" \(p. 290\)](#).

## 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 \(p. 25\)](#).

The Go bindings for the AWS CDK use the standard [Go toolchain](#), v1.16 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 AWS CDK Go module, `github.com/aws/aws-cdk-go/awscdk`, in `go.mod`. The CDK and its dependencies are automatically installed when you build your app.

## Managing AWS Construct Library modules

In most AWS CDK documentation and examples, the word "module" is used primarily 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`. Packages for the various services in the AWS Construct Library live under `github.com/aws/aws-cdk-go/awscdk`. For example, the Amazon S3 module's namespace is `github.com/aws/aws-cdk-go/awscdk/awss3`.

```
import (
    "github.com/aws/aws-cdk-go/awscdk/awss3" 2.16.0
    // ...
)
```

The contents of the Amazon S3 Go package are then available in the `awss3` namespace. For example, to instantiate a bucket, you would call `awss3.NewBucket()`.

You may specify an alias when importing if you prefer more concise names:

```
import (
    s3 "github.com/aws/aws-cdk-go/awscdk/awss3" // use s3.NewBucket etc.
    // ...
)
```

The code examples in this guide use the actual Go package names, so it is clear which Go packages (AWS Construct Library modules) are needed.

## 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`).

## 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, you can 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 it. 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 \(p. 91\)](#) 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" \(p. 290\)](#).

# Managing dependencies

Dependencies for your AWS CDK app or library are managed using package management tools commonly used with the programming language in which you develop your app. 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 may also be able to use other tools, especially if they interoperate with the supported tools, although our ability to support alternatives is limited.

The CDK supports the following package managers.

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

## Note

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

The remainder of this topic provides details on using AWS CDK dependencies in each language.

## TypeScript and JavaScript

In TypeScript and JavaScript CDK projects, dependencies are specified in `package.json` in the project's main directory. Every AWS Construct Library module is a separate NPM package. All versions of AWS CDK packages match and specify a single version, and the same version. If the versions are different, NPM is likely to install multiple copies of CDK libraries, and you will see unpredictable compilation or runtime errors.

## Tip

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

If you prefer, you may use Yarn in place of NPM. However, the CDK does not support Yarn's plug-and-play mode, which is default mode in Yarn 2. Add the following to your project's `.yarnrc.yml` file to disable this feature.

```
nodeLinker: node-modules
```

## Applications

The following is an example `package.json` generated by **cdk init --language typescript**. The file generated for JavaScript is similar, just without the TypeScript-related entries.



```
{
  "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": {
    "@aws-cdk/assert": "1.121.0",
    "@types/jest": "^26.0.10",
    "@types/node": "10.17.27",
    "jest": "^26.4.2",
    "ts-jest": "^26.2.0",
    "aws-cdk": "1.121.0",
    "ts-node": "^9.0.0",
    "typescript": "~3.9.7"
  },
  "dependencies": {
    "@aws-cdk/core": "1.121.0",
    "source-map-support": "^0.5.16"
  }
}
```

All CDK apps use `@aws-cdk/core`, which must be specified in the `dependencies` section of `package.json` along with all other AWS Construct Library module your app uses.

**Note**

All AWS CDK dependencies must have the same version.

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/core": "1.140.0",
    "@aws-cdk/aws-s3": "1.140.0",
    "@aws-cdk/aws-iam": "1.140.0"
  },
  "devDependencies": {
    "jsii": "^1.50.0",
    "aws-cdk": "^1.140.0"
  }
}
```

In `peerDependencies`, use a caret (^) to specify the lowest version of the AWS CDK packages that your library works with, to maximize the compatibility of your library with a range of CDK versions. Using `peerDependencies` makes sure 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 version of the CDK packages that you advertise your library be compatible with. This practice ensures that your tests run against those versions, so that 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`, or they will not 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 **npm install** and **yarn upgrade** commands given above can be used. Either command updates the packages in `node_modules` to the latest versions that satisfy the rules in `package.json`, but 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, which allows each project to have its own versions of dependencies, as well as 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.core==1.140.0
aws-cdk.aws-s3==1.140.0
aws-cdk.aws-iam==1.140.0
```

### Note

All AWS CDK dependencies must have the same version.

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 and used as a requirements file with `pip install -r`. This file is convenient for pinning all dependencies (including transitive ones) to the exact versions you tested with. To avoid problems when upgrading packages later, use a separate file for this, e.g. `freeze.txt` not `requirements.txt`, and 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.core==1.140.0',
        'aws-cdk.aws-s3==1.140.0',
        'aws-cdk.aws-iam==1.140.0',
    ],
    ...
)
```

### Note

All AWS CDK dependencies must have the same version.

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.

```
<properties>
  <cdk.version>1.140.0</cdk.version>
</properties>

<dependencies>
  <dependency>
    <groupId>software.amazon.awscdk</groupId>
    <artifactId>core</artifactId>
    <version>${cdk.version}</version>
  </dependency>
  <dependency>
    <groupId>software.amazon.awscdk</groupId>
    <artifactId>s3</artifactId>
    <version>${cdk.version}</version>
  </dependency>
  <dependency>
    <groupId>software.amazon.awscdk</groupId>
    <artifactId>iam</artifactId>
    <version>${cdk.version}</version>
  </dependency>
</dependencies>
```

### Note

All AWS CDK dependencies must have the same version. To make it easier to update the versions of these packages while keeping them in sync, we define a property with the desired CDK version.

Maven does not support dependency locking, so while it is 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 allow you to specify version ranges for dependencies. Every dependency is pinned to a specific version.

### Note

All AWS CDK dependencies must have the same 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.

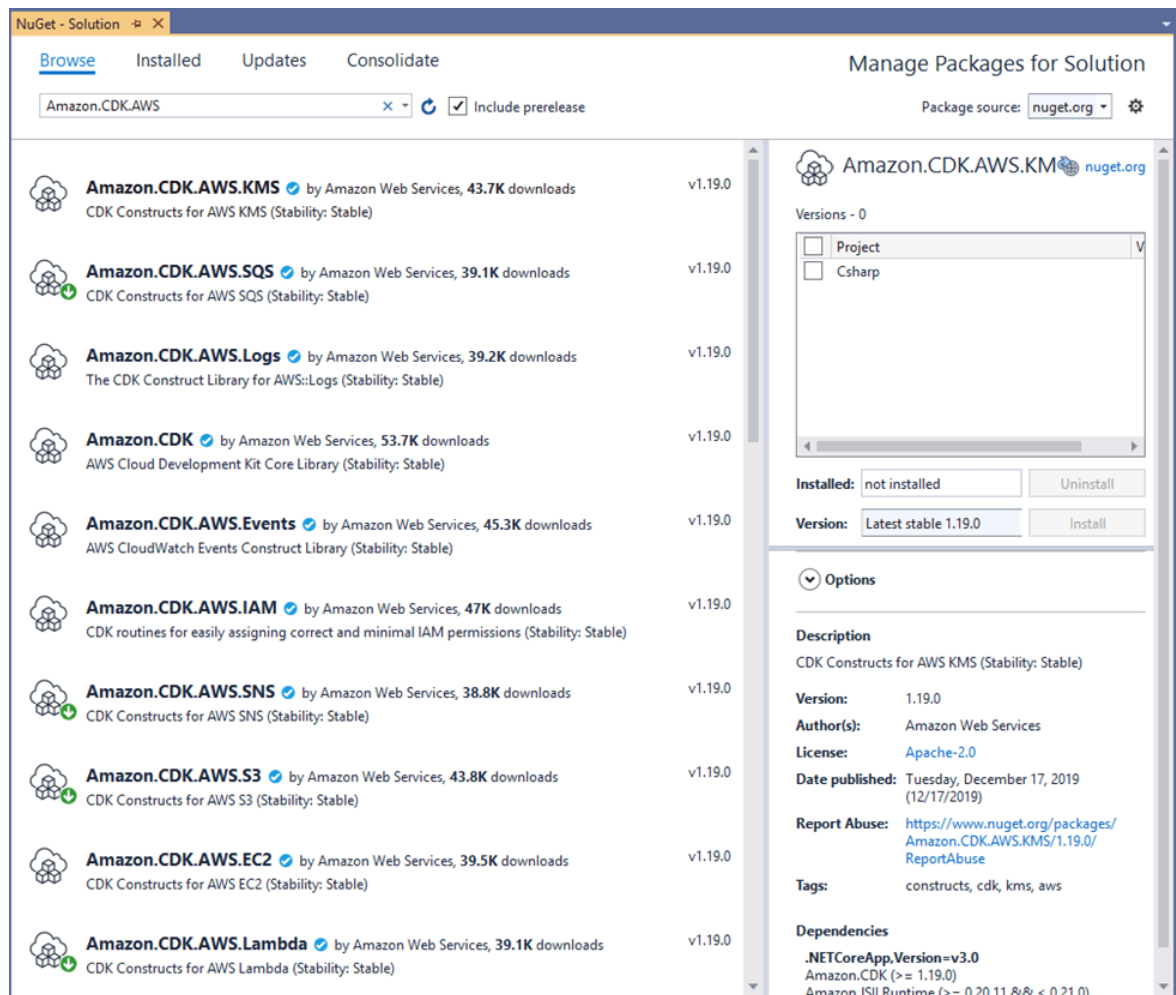
## Editing the project file directly

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

```
<ItemGroup>
  <PackageReference Include="Amazon.CDK" Version="1.140.0" />
  <PackageReference Include="Amazon.CDK.AWS.S3" Version="1.140.0" />
  <PackageReference Include="Amazon.CDK.AWS.IAM" Version="1.140.0" />
</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 pre-release versions of your modules and add them to any of the open projects.



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. 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 -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.

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 version number appended. Go's module system does not support version ranges, so all dependencies must be pinned to a specific version.

Go automatically downloads dependencies whenever you build. The CDK does this for you automatically whenever you run your app, so there is no need to do it manually.

You may use the **`go get`** command to install a module 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 CDK provides an improved development experience that aims to make Infrastructure as Code (IAC) even simpler.

CDK v1 entered maintenance on June 1, 2022. During the maintenance phase, CDK v1 will receive critical bug fixes and security patches only, and new features will be developed exclusively for CDK v2. On June 1, 2023, support will end entirely for AWS CDK v1. For more details, see [AWS CDK Maintenance Policy](#).

For information on migrating your apps to AWS CDK v2, see [Migrating to AWS CDK v2](#) in the AWS CDK v2 Developer Guide.

## Tip

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

## CDK Toolkit v2 compatibility

CDK v2 requires v2 or later of the CDK Toolkit. This version is backward-compatible with CDK v1 apps, so 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.

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

## Tip

Set up command line aliases so you can use **cdk** and **cdk2** commands to invoke the desired version of the CDK Toolkit.

macOS/Linux

```
alias cdk="npm aws-cdk@1.x"
alias cdk2="npm aws-cdk@2.x"
```

Windows

```
doskey cdk=npm aws-cdk@1.x $*
doskey cdk2=npm aws-cdk@2.x $*
```



# Translating TypeScript AWS CDK code to other languages

TypeScript was the first language supported for developing AWS CDK applications, and for that reason, there is a substantial amount of example CDK code written in TypeScript. If you are developing in another language, it may be useful to compare how AWS CDK code is implemented in TypeScript and your language of choice, so you can, with a little effort, make use of these examples.

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

- [the section called “In TypeScript” \(p. 27\)](#)
- [the section called “In JavaScript” \(p. 31\)](#)
- [the section called “In Python” \(p. 37\)](#)
- [the section called “In Java” \(p. 43\)](#)
- [the section called “In C#” \(p. 47\)](#)

## 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 namespace as s3 into current namespace
import * as s3 from '@aws-cdk-lib/aws-s3';

// Import namespace using Node.js require() (import * as s3 generally preferred)
const s3 = require('@aws-cdk-lib/aws-s3');

// TypeScript version of require() (again, import * as s3 generally preferred)
import s3 = require('@aws-cdk/aws-s3');

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

// Selective import of s3.Bucket into current namespace
import { Bucket } from '@aws-cdk/aws-s3';

// Selective import of Bucket and EventType into current namespace
import { Bucket, EventType } from '@aws-cdk/aws-s3';

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

### Python

Like TypeScript, Python supports namespaced module imports and selective imports. Module names in Python look like **aws\_cdk.xxx**, where **xxx** represents an AWS service name, such as **s3** for Amazon S3 (we'll use Amazon S3 for our examples).

```
# 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

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

# 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.

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

```
// 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, which give you access either all the types in the specified namespace using their plain names, or let you refer to the namespace itself using an alias.

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

## 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 is the only one that doesn't). Also, in most languages, the keyword `this` refers to the current instance. Python, again, is the exception (it 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 a 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 sub-properties.

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, and there is also a convenient builder for each construct that builds the props and the construct in one step, as shown here.

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"
    }
});
```

# Accessing members

It is common to refer to attributes or properties of constructs and other AWS CDK classes and use these values as, for examples, inputs to build other constructs. The naming differences described above for

methods apply. 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
```

## 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, qualified enum names are also the same.

```
s3.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 interface(s) it implements 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/core';

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.core 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.core.IAspect;
import software.amazon.awscdk.core.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}");
    }
}
```

# 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 \(p. 71\)](#), 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) and are 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, or it can 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.

## 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.

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, which requires a complete understanding of the details of the underlying AWS CloudFormation resource model.

The next level of constructs, **L2**, also represent AWS resources, but with a higher-level, intent-based API. They provide similar functionality, but provide 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, while providing 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.

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 (ALB). 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, and 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 you want to deploy using 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, auto-scaling, and monitoring, and share it with other teams in their organization, or publicly. Teams can now use this construct as they would any other library package in their preferred programming language to define their tables and comply with their team's 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 \(p. 86\)](#). You should usually pass this (or `self` in Python), which represents the current object, for the scope.
- **id** — An [identifier \(p. 124\)](#) that must be unique within this scope. The identifier serves as a namespace for everything that's defined within the current construct and is used to generate unique identifiers such as [resource names \(p. 112\)](#) 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 leave out 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, for example for [tagging](#) or for 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/core';
```



```
import * as s3 from '@aws-cdk/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/core');
const s3 = require('@aws-cdk/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.core import App, Stack
from aws_cdk import aws_s3 as s3

class HelloCdkStack(core.Stack):

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

        s3.Bucket(self, "MyFirstBucket", versioned=True)

app = core.App()
HelloCdkStack(app, "HelloCdkStack")
```

### Java

```
import software.amazon.awscdk.core.*;
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 });
        }
    }
}
```

As you can see, you need a scope within which to define your bucket. Since resources eventually need to be deployed as part of a AWS CloudFormation stack into an AWS [environment \(p. 98\)](#), which 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. This is a common pattern when creating a stack within your AWS CDK app: 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**, as shown in the following example.

#### 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(core.Stack):  
  
    def __init__(self, scope: core.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"  
});
```

In Python, Java, and C#, L1 construct properties that aren't simple Booleans, strings, numbers, or containers 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.

#### 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

```
bucket = CfnBucket(self, "MyBucket", bucket_name="MyBucket",  
    cors_configuration=CfnBucket.CorsConfigurationProperty(  
        cors_rules=[CfnBucket.CorsRuleProperty(  
            allowed_origins=["*"],  
            allowed_methods=["GET"]  
        )]  
    )  
)
```

#### Java

```
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#

```
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" },
            }
        }
    }
});
```

#### Important

You can't use L2 property types with L1 constructs, or vice versa. When working with L1 constructs, always use the types defined inside 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, just 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/aws-s3';

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

#### JavaScript

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

// "this" is HelloCdkStack
new s3.Bucket(this, 'MyFirstBucket', {
```

```
    versioned: true
  });
```

#### Python

```
from aws_cdk import 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
});
```

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"
});
```

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 enable you to 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 wish. However, the AWS constructs that are included with the AWS Construct Library, such as `s3.Bucket`, follow guidelines and common patterns in order to provide a consistent experience across all AWS resources.

For example, almost all AWS constructs have a set of [grant](#) (p. 160) 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);
```

Another common pattern is for AWS constructs to set one of the resource's attributes, such as its Amazon Resource Name (ARN), name, or URL from data supplied elsewhere. For example, 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_14_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_14_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_14_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_14_X,
    Handler = "index.handler",
    Code = Code.FromAsset(@".\create-job-lambda-code"),
    Environment = new Dictionary<string, string>
    {
        ["QUEUE_URL"] = jobsQueue.QueueUrl
    }
});
```

For information about the most common API patterns in the AWS Construct Library, see [the section called “Resources” \(p. 104\)](#).

## 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 that someone published via NPM or Maven or PyPI—or to your company's internal package repository.

To declare a new construct, create a class that extends the [Construct](#) base class, then follow the pattern for initializer arguments.

For example, you could declare a construct that represents an Amazon S3 bucket which 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(core.Construct):

    def __init__(self, scope: core.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
    });
}
```

### 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");
```

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"  
});
```

Typically, you would also want to expose some properties or methods on your constructs. For example, it's not very useful to have a topic hidden behind your construct, because it wouldn't be possible for users of your construct to subscribe to it. Adding a topic property allows consumers to 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(core.Construct):  
  
    def __init__(self, scope: core.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
        });
    }
}
```

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));
```

## 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 never any 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 `core.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, which allows you to 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 virtually 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 need

be unique only within their scope, rather than within the entire stack as in native AWS CloudFormation. It does, however, mean that if you move a construct to a different scope, its generated stack-unique ID will change, and AWS CloudFormation will no longer consider it the same resource.

The construct tree is separate from the constructs you define in your AWS CDK code, but it is 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 `ConstructNode` 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 will generally infer the dependency and make sure the resources are created in the right order. You can also add an explicit dependency between two nodes using `node.addDependency()`; 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. See [the section called “Aspects” \(p. 174\)](#).

## Apps

As described in [the section called “Constructs” \(p. 71\)](#), 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. However, this only declares a stack. You still need to define (also known as to instantiate) it in some scope to deploy it.

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 a AWS CloudFormation template and deployed, it needs to 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();
```

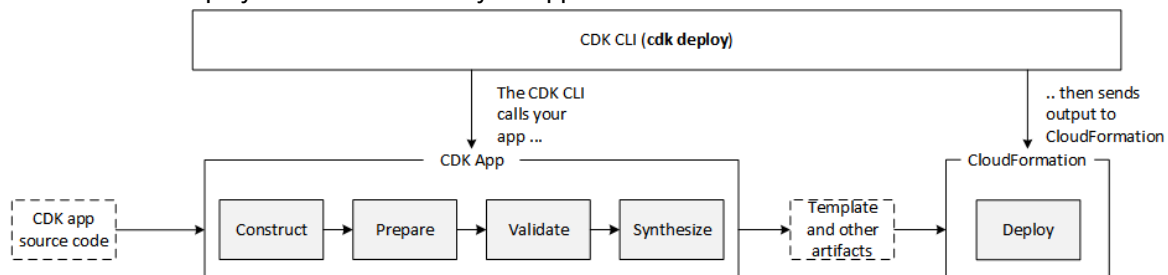
### C#

```
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. You should 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 that you perform validation as soon as possible (usually as soon as you get some input) and throw 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" \(p. 90\)](#) 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, and then 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 \(p. 199\)](#). 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" \(p. 128\)](#) 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, and 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 that specifies the

necessary command for the language 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 did not create your project using the CDK Toolkit, or wish 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, just 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, and can be either defined directly within the scope of the app, like the `MyFirstStack` example shown previously, or 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 the value of a parameter, you must set up an [AWS CloudFormation condition](#) and tag the resource with this condition. Because the AWS CDK takes an approach where concrete templates are resolved at synthesis time, 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, Construct, Stack } from "@aws-cdk/core";

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 , Construct , Stack } = require("@aws-cdk/core");

// 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.core import App, Construct, Stack

# 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.core.App;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.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;

// 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
prodcpl87264CE
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, but you can specify an explicit name 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 either the account or Region explicitly specified when the stack was defined, or a string-encoded token that resolves to the AWS CloudFormation pseudo-parameters for account and Region to indicate that this stack is environment agnostic. See [the section called “Environments” \(p. 98\)](#) for information about how environments are determined for stacks.
- `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, but for environment-specific stacks, the AWS CDK queries the environment and returns the exact set of Availability Zones available in the region 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`) – Enables you 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, but can itself 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 needn't 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 are not listed by `cdk list` nor can they 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. 107).

### 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; see [Regional endpoints](#) for a list.

### Note

For all but the simplest deployments, you will need to [bootstrap](#) (p. 177) each environment you will deploy into. Deployment requires certain AWS resources to be available, and these resources are provisioned by bootstrapping.

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 deployment-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 (or the default profile, if none is specified) to determine where to deploy. 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” \(p. 290\)](#) 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 = core.Environment(account="8373873873", region="eu-west-1")
env_USA = core.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 hard-code the target account and region as above, the stack will always be 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, but if you are working with a project created before it was added, or didn't set up your project using `cdk init`, install it manually.

```
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=core.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 do not work at all without an explicit environment specified; 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 allows environment-dependent code to work, but it also means that the synthesized

template could be different based on the machine, user, or session under which it is synthesized. 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, we use our alternative environment variables if they're set, falling back to the default environment provided by the AWS CDK if they are not.

#### 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=core.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 now 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" \(p. 71\)](#), 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 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” \(p. 128\)](#) 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 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 pattern generally used is:

- 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 }
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, "Stack2",
    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 to ensure that they are deployed in the right order. Once this dependency has been made concrete by deploying the stacks, 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, but 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 is no longer needed, but the exported resource is still being used in the consuming stack because its update has not yet been deployed, so deploying the producer stack fails.

To break this deadlock, remove the use of the shared resource from the consuming stack (which will remove the automatic export from the producing stack), then 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 is 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: for example, 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 that 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, and 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 a 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, since 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" \(p. 98\)](#)). If the AWS CDK attempts to look up an Amazon VPC from an [environment-agnostic stack \(p. 97\)](#), the CDK Toolkit does not 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 specifying that you want the VPC marked as the default is sufficient.

#### 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. Tags may be added to the Amazon VPC at the time of its creation using AWS CloudFormation or the AWS CDK, and they may be edited at any time after creation using the AWS Management Console, the AWS CLI, or an AWS SDK. In addition to any tags you have added 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" \(p. 167\)](#).) Commit this file to version control so that your app will continue to refer to the same Amazon VPC 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 will be deploying the stack

in an environment that does not have access to the AWS account that defines the VPC, such as [CDK Pipelines](#) (p. 266).

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 AWS CloudFormation has deployed the resources. 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 by using 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. For example, when you are using the low-level AWS CloudFormation resources, or 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
    }
});
```

## Permission grants

AWS constructs make least-privilege permissions easy to achieve by offering simple, intent-based APIs to express permission requirements. Many AWS constructs offer grant methods that enable you to easily grant an entity, such as an IAM role or a user, permission to work with the resource without having to manually craft one or more 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 using an AWS KMS key, this method also grants the Lambda function's execution role permissions to decrypt using this 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. 106)). 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 allow easy access to the metrics without having to look 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, for example, 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 by using 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_notes  
  
handler = lambda_.Function(self, "Handler", ...)  
bucket = s3.Bucket(self, "Bucket")  
bucket.add_object_created_notification(s3_notes.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 s3Notifs = 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 s3Notifs.LambdaDestination(handler));
```

## Removal policies

Resources that maintain persistent data, such as databases and Amazon S3 buckets and even Amazon ECR registries, have a *removal policy* that 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 may 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 a 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, including AWS CloudFormation stacks, Amazon Cognito user pools, Amazon DocumentDB database instances, Amazon EC2 volumes, Amazon OpenSearch Service domains, Amazon FSx file systems, and 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`, but 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, need only 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 you use to refer to it in the [the section called “AWS CDK Toolkit” \(p. 290\)](#).

Let's look at an example where we have two constructs with the identifier `MyBucket` in our app. However, since they are defined in different scopes, the first in the scope of the stack with the identifier `Stack1`, and the second in the scope of a stack with the identifier `Stack2`, that doesn't cause any sort of conflict, and they can coexist in the same app without any issues.

### TypeScript

```
import { App, Construct, Stack, StackProps } from '@aws-cdk/core';
import * as s3 from '@aws-cdk/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/core');
const s3 = require('@aws-cdk/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.core import App, Construct, Stack, StackProps
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.core.App;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.StackProps;
import software.amazon.awscdk.services.s3.Bucket;

public class MyStack extends Stack {
    public MyStack(final App scope, final String id) {
        this(scope, id, null);
    }

    public MyStack(final App scope, final String id, final StackProps props) {
        super(scope, id, props);
        new Bucket(this, "MyBucket");
    }
}

// Main.java
package com.myorg;

import software.amazon.awscdk.core.App;

public class Main {
    public static void main(String[] args) {
        App app = new App();
        new MyStack(app, "Stack1");
        new MyStack(app, "Stack2");
    }
}
```

## C#

```
using core = Amazon.CDK;
```

```
using s3 = Amazon.CDK.AWS.S3;

public class MyStack : core.Stack
{
    public MyStack(core.App scope, string id, core.IStackProps props) : base(scope, id,
    props)
    {
        new s3.Bucket(this, "MyBucket");
    }
}

class Program
{
    static void Main(string[] args)
    {
        var app = new core.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, with the IDs from the levels separated by slashes, starting at the node just below 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, which 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 a 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

Since AWS CloudFormation requires that all logical IDs in a template are unique, 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) so 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, since 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, but 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*, which are sometimes called *logical names*, of resources in the generated AWS CloudFormation templates for those 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 with the logical ID `Stack2MyBucket4DD88B4F` in the resulting AWS CloudFormation template.

### Logical ID stability

Avoid changing the logical ID of a resource after it has been created. Since AWS CloudFormation identifies resources by their logical ID, 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 may cause service interruption or 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” \(p. 89\)](#)). 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, such as in the following example, where 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 using static methods on the [core.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 will fail. Similarly, if you attempt to query the length of an array, or perform math operations with a number, you must first verify that they are not 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 ensure 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 \(p. 134\)](#), 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, just 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 may 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+  
    "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. Since the AWS CDK synthesizes AWS CloudFormation templates, it too offers support for deployment-time parameters.

Using the AWS CDK, you can both define parameters, which can then be used in the properties of constructs you create, and you can also deploy stacks containing 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 \(p. 167\)](#) 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, as well as at synthesis time. This makes it harder to understand and reason about your AWS CDK application, in many cases for little benefit.

It is better, again in general, to have your CDK app accept any necessary information in some 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. Additionally, the AWS CDK's support for AWS CloudFormation parameters lets you use the AWS CDK with AWS services that use AWS CloudFormation templates (such as AWS Service Catalog), which use parameters to configure the template 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, but we recommend defining parameters at the stack level so that their logical ID does not 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 \(p. 128\)](#). 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, depending on the type of value required by the class or method 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
<code>value_as_list</code>	The token represented as a string list
<code>value_as_number</code>	The token represented as a number



Property	kind of value
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 may provide these on the command line following the `--parameters` flag. You might deploy a stack that uses the `uploadBucketName` parameter like this.

```
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 by prefixing 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 to simplify management, in cost allocation, and for access control, as well as for any other purposes you devise.

### Tip

For more information about how you can use tags with your AWS resources, see the white paper [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" \(p. 174\)](#). 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) and removing a tag has a priority of 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, but not 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/core';

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/core');
```

```
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.core 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.core.App;
import software.amazon.awscdk.core.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, but here, the value could be different for each tagged construct.

Tags are implemented using [aspects \(p. 174\)](#), 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(construct);
```

#### JavaScript

```
new cdk.Tag(key, value).visit(construct);
```

#### Python

```
cdk.Tag(key, value).visit(construct)
```

#### Java

```
Tag.Builder.create(key, value).build().visit(construct);
```



## C#

```
new Tag(key, value).Visit(construct);
```

To tag all constructs under a scope but allow the values of the tags to be derived from properties of each construct, write an aspect, apply the tag in the aspect's `visit()` method as shown above, and add the aspect to the desired scope using `Aspects.of(scope).add(aspect)`.

The example below 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, so you can use these features when applying tags to arbitrary resources. 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, 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. 90) synthesized from your application includes metadata information with instructions for the AWS CDK CLI on where to find the asset on the local disk, and what type of bundling to perform based on the type of asset, such as a directory to compress (zip) or a Docker image to build.

The AWS CDK generates a source hash for assets, which 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 is so that the cloud assembly is self-contained and moved over to a different host for deployment. See [the section called "Cloud assemblies" \(p. 90\)](#) for details.

The AWS CDK also synthesizes AWS CloudFormation parameters that the AWS CDK CLI specifies during deployment. The AWS CDK uses those parameters to refer to the deploy-time values of the asset.

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 them to Amazon S3 or Amazon ECR, and only then deploys the stack. The AWS CDK specifies the locations of the published assets as AWS CloudFormation parameters to the relevant stacks, and uses that information to enable referencing these locations within an AWS CDK app.

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/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/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 that enable you to 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 to create AWS Lambda functions with the handler code, which is the entry point for the function, as an Amazon S3 asset.

The following example uses an Amazon S3 asset to define a Python handler in the local directory `handler` and creates a Lambda function with the local directory asset as the code property. Below 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/core';
```

```
import * as lambda from '@aws-cdk/aws-lambda';
import * as path from 'path';

export class HelloAssetStack extends cdk.Stack {
  constructor(scope: cdk.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/core');
const lambda = require('@aws-cdk/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.core import Stack, 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.core.Stack;
import software.amazon.awscdk.core.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 will be uploaded as-is to Amazon S3, but when they are deployed as a Lambda function, the files they contain will be extracted, which probably isn't what you 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. 105) 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 just an example.)

#### TypeScript

```
import { Asset } from '@aws-cdk/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/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

from aws_cdk import 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.core.Stack;
import software.amazon.awscdk.core.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 need to read assets in runtime, 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/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/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
from aws_cdk import 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.core.Stack;
import software.amazon.awscdk.core.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, and can be naturally referenced in your AWS CDK app.

### TypeScript

```
import { DockerImageAsset } from '@aws-cdk/aws-ecr-assets';

const asset = new DockerImageAsset(this, 'MyBuildImage', {
    directory: path.join(__dirname, 'my-image')
});
```

### JavaScript

```
const { DockerImageAsset } = require('@aws-cdk/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(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 [deploy-time attributes](#) (p. 105) 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/aws-ecs';
import * as path from 'path';

const taskDefinition = new ecs.FargateTaskDefinition(this, "TaskDef", {
    memoryLimitMiB: 1024,
    cpu: 512
});

taskDefinition.addContainer("my-other-container", {
    image: ecs.ContainerImage.fromAsset(path.join(__dirname, "..", "demo-image"))
});
```

### JavaScript

```
const ecs = require('@aws-cdk/aws-ecs');
const path = require('path');

const taskDefinition = new ecs.FargateTaskDefinition(this, "TaskDef", {
    memoryLimitMiB: 1024,
    cpu: 512
});

taskDefinition.addContainer("my-other-container", {
    image: ecs.ContainerImage.fromAsset(path.join(__dirname, "..", "demo-image"))
});
```

### Python

```
import aws_cdk.aws_ecs as ecs

import os.path
dirname = os.path.dirname(__file__)

task_definition = ecs.FargateTaskDefinition(self, "TaskDef",
    memory_limit_mib=1024,
    cpu=512)

task_definition.add_container("my-other-container",
    image=ecs.ContainerImage.from_asset(
        os.path.join(dirname, "..", "demo-image")))
```

## 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;

File startDir = new File(System.getProperty("user.dir"));

FargateTaskDefinition taskDefinition = FargateTaskDefinition.Builder.create(
    this, "TaskDef").memoryLimitMiB(1024).cpu(512).build();

taskDefinition.addContainer("my-other-container",
    ContainerDefinitionOptions.builder()
        .image(ContainerImage.fromAsset(new File(startDir,
            "demo-image").toString())).build());
```

## C#

```
using System.IO;
using Amazon.CDK.AWS.ECS;

var taskDefinition = new FargateTaskDefinition(this, "TaskDef", new
    FargateTaskDefinitionProps
    {
        MemoryLimitMiB = 1024,
        Cpu = 512
    });

taskDefinition.AddContainer("my-other-container", new ContainerDefinitionOptions
    {
        Image = ContainerImage.FromAsset(Path.Combine(Directory.GetCurrentDirectory(),
            "demo-image"));
    });
```

## 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/aws-ecs';
import * as path from 'path';
import { DockerImageAsset } from '@aws-cdk/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/aws-ecs');
const path = require('path');
const { DockerImageAsset } = require('@aws-cdk/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, you need to ensure 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 is an AWS service, such as AWS CodeBuild, that does not assume a role in your account, 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" \(p. 311\)](#) 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.

## 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 (i.e. its members) write access to a Amazon RDS table, but the group itself is not a principal since it does not 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. Traditional 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 without having 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, 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 code below 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 a 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 you didn't forget to set the policies). In those cases, the deployment may 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/aws-iam';

const role = new iam.Role(this, 'Role', {
  assumedBy: new iam.ServicePrincipal('ec2.amazonaws.com'), // required
});
```

### JavaScript

```
const iam = require('@aws-cdk/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 our example above, 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 either pass in an existing role when instantiating the construct object, or 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/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/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`. This property is not available on external resources, however, so such constructs have an `addToRolePolicy` (Python: `add_to_role_policy`) method that does nothing if the construct is a reference to an external resource, and calls the `addToPolicy` (Python: `add_to_policy`) method of the role property otherwise, saving 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 by creating a reference to it using its ARN or (for users, groups, and roles) its name. The returned reference can then be used to grant permissions or to construct policy statements as explained above.

- 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 referenced in similar fashion using the methods listed below. 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 IAM references returned by the above methods 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, such as 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, which 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.

Without context caching, if you had specified "latest Amazon Linux" as the AMI for your Amazon EC2 instances, and a new version of this AMI were released, then the next time you deployed your CDK stack, your already-deployed instances would be using the outdated ("wrong") AMI and would therefore 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, and you can 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” \(p. 173\)](#) 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 context key below 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 do not represent cached values should be stored under the context key of `cdk.json` so 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 are 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) may 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 set by the AWS CDK Toolkit (the **cdk** command), whether automatically, from a file, or from the **--context** option, are implicitly set on the App construct, and so are 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 is not found on the current construct or any of its parents, the result is undefined (or 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. The CLI then queries the current AWS account for the information, stores the resulting context information in the `cdk.context.json` file, and 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, which is the list of availability zones in the 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, you can use the preceding example to do a controlled update of the context value and reset it, and 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. To protect a context value from being reset using these commands, then, 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. To allow non-string context values provided in other ways (for example, in `cdk.context.json`) to work as expected, make sure the value is a string before converting it.

## Example

Below is an example of referencing an existing Amazon VPC using AWS CDK context.

TypeScript

```
import * as cdk from '@aws-cdk/core';
import * as ec2 from '@aws-cdk/aws-ec2';

export class ExistsVpcStack extends cdk.Stack {

  constructor(scope: cdk.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/core');
const ec2 = require('@aws-cdk/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.core as cdk
import aws_cdk.aws_ec2 as ec2

class ExistsVpcStack(cdk.Stack):

    def __init__(self, scope: cdk.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(subnet_type=ec2.SubnetType.PUBLIC)

        cdk.CfnOutput(self, "publicsubnets",
            value=pubsubnets.subnet_ids.to_string())
```

### Java

```
import software.amazon.awscdk.core.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;

public class ExistsVpcStack extends Stack {
    public ExistsVpcStack(App context, String id) {
        this(context, id, null);
    }

    public ExistsVpcStack(App 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;

class ExistsVpcStack : Stack
{
    public ExistsVpcStack(App 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" \(p. 167\)](#) values in `cdk.json` (or `~/.cdk.json`) as shown here.

```
{
  "app": "npx ts-node bin/tscdk.ts",
  "context": {
    "@aws-cdk/core:enableStackNameDuplicates": true
  }
}
```

The names of all feature flags begin with the NPM name of the package affected by the particular flag. In the example above, this is `@aws-cdk/core`, the AWS CDK framework itself, since the flag affects stack naming rules, a core AWS CDK function. AWS Construct Library modules can also use feature flags.

Feature flags are disabled by default, so existing projects that do not specify the flag will continue to work as expected 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 old behavior, or to add flags to enable new behaviors after upgrading the AWS CDK.

See the CHANGelog in a given release for a description of any new feature flags added in that release. The AWS CDK source file [features.ts](#) provides a complete list of all current feature flags.

As feature flags are stored in `cdk.json`, they are not removed by the `cdk context --reset` or `cdk context --clear` commands.

## 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 ensuring 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. 138), 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, so 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, so 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 \(p. 89\)](#), 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, which 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(core.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

Deploying AWS CDK apps into an AWS [environment](#) (p. 98) (a combination of an AWS account and region) may require that you provision resources the AWS CDK needs to perform the deployment. These resources include an Amazon S3 bucket for storing files and IAM roles that grant permissions needed to perform deployments. The process of provisioning these initial resources is called *bootstrapping*.

An environment needs to be bootstrapped if any of the following apply.

- An AWS CDK stack being deployed uses [the section called "Assets"](#) (p. 146).
- An AWS CloudFormation template generated by the app exceeds 50 kilobytes.
- One or more of the stacks uses the `DefaultSynthesizer`. We will explain stack synthesizers in more detail shortly, but in brief, the `DefaultSynthesizer` is used if you have set the `@aws-cdk/core:newStyleStackSynthesis` [feature flag](#) (p. 173) in your app's `cdk.json` or if you explicitly create a `DefaultSynthesizer` and pass it to your stack. [CDK Pipelines](#) (p. 266) use the `DefaultSynthesizer`, so if your app uses CDK Pipelines, you must bootstrap the environments you will deploy into as well as the environment that contains the pipeline.

The required resources are defined in a 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.

The AWS CDK supports two bootstrap templates. At this writing, the AWS CDK is transitioning from one of these templates to the other, but the original template (dubbed "legacy") is still the default. The newer template ("modern") is required by CDK Pipelines today, and will become the default at some point in the future. For details, see [the section called "Bootstrapping templates"](#) (p. 179).

Environments are independent, so 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

Older versions of the modern template created a Customer Master Key (CMK) in each bootstrapped environment by default. To avoid charges for the CMK, re-bootstrap these environments using `--no-bootstrap-customer-key`. The current default is to not use a CMK to avoid these charges.

If you attempt to deploy an AWS CDK application that requires bootstrap resources into an environment that does not have them, you receive an error message telling you that you need to bootstrap.

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, which is most likely caused by 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 a 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" \(p. 181\)](#)). 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 Stack Sets or AWS Control Tower as well as the AWS CloudFormation console or the AWS CLI. You can even 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 (that is, it does not have an `env` property), the CDK's environment (for example, the one specified using `--profile`, or the default AWS environment otherwise) is applied to make the stack environment-specific, and 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 `cdk bootstrap --template TEMPLATE_FILENAME` or your preferred deployment mechanism for AWS CloudFormation templates. For example, the following command deploys the template using the AWS CLI:

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 templates

At this writing, the AWS CDK is transitioning from one set of bootstrap resources to another. The original bootstrap template, which shipped with the very first version of the AWS CDK, is called the **legacy** template. A newer version of the template with additional resources was added in version 1.25.0. This newer template is called the **modern** template.

The legacy template is still fully supported by the AWS CDK and is in fact the template that is selected by default when you issue `cdk bootstrap`. The modern template is required primarily by the CDK

Pipelines module, which can be used to set up a continuous delivery pipeline for your CDK applications. More precisely, the modern template is used by the `DefaultSynthesizer` (see [the section called “Stack synthesizers”](#) (p. 182)), and CDK Pipelines requires this synthesizer,

The main differences between the templates are as follows.

Feature	Legacy	Modern
Cross-account deployments	Not allowed	Allowed
AWS CloudFormation Permissions	Deploys using current user's permissions (determined by AWS profile, environment variables, etc.)	Deploys using the permissions specified when the bootstrap stack was provisioned (e.g. using <code>--trust</code> )
Versioning	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
Resources*	Amazon S3 bucket	Amazon S3 bucket
		AWS KMS key
		IAM roles
		Amazon ECR repository
		SSM parameter for versioning
Resource naming	Automatically generated	Deterministic
Bucket encryption	Default key	Customer-managed key

\* We will add additional resources to the modern template as needed.

In AWS CDK version 2, the modern template will be the default bootstrapping template. In version 1, manually select the modern template when bootstrapping by setting the `CDK_NEW_BOOTSTRAP` environment variable.

macOS/Linux

```
export CDK_NEW_BOOTSTRAP=1
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

Windows

```
set CDK_NEW_BOOTSTRAP=1
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

The modern template is also selected when you issue **cdk bootstrap** in an AWS CDK app directory where the `@aws-cdk/core:newStyleStackSynthesis` feature flag is set in the app's `cdk.json` file.

```
{
  // ...
```

```
"context": {  
  "@aws-cdk/core:newStyleStackSynthesis": true  
}
```

### Tip

We recommend always setting `CDK_NEW_BOOTSTRAP` when you want to bootstrap using the modern template. The context key is supported to make sure you bootstrap correctly if your app uses the `DefaultStackSynthesizer`, but relies on you being in an app's directory when bootstrapping.

These two ways to specify the modern template also apply to `cdk bootstrap --show-template`, which will display the modern template if either of these flags is present.

If the environment you are bootstrapping with the modern template has already been bootstrapped with the legacy template, the environment is upgraded to the modern template. The Amazon S3 bucket from the legacy stack is orphaned in the process. 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 unlimited 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" \(p. 182\)](#)).
- **--bootstrap-kms-key-id** overrides the AWS KMS key used to encrypt the S3 bucket.
- **--tags** adds one or more AWS CloudFormation tags to the bootstrap stack.
- **--termination-protection** prevents the bootstrap stack from being deleted (see [Protecting a stack from being deleted](#) in the AWS CloudFormation User Guide)

The following additional switches are available only with the modern bootstrapping template.

- **--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 privileges 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 you specify are sufficient for any deployments you will perform in the environment being bootstrapped.

- **--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.
- **--qualifier** 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 using **--toolkit-stack-name**. 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 (see [the section called “Stack synthesizers” \(p. 182\)](#)).

### Important

The modern bootstrap template effectively grants the permissions implied by the `--cloudformation-execution-policies` to any AWS account in the `--trust` list, which by default will extend permissions to read and write to any resource in the bootstrapped account. Make sure to [configure the bootstrapping stack \(p. 181\)](#) with policies and trusted accounts 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. Optionally, set the **CDK\_NEW\_BOOTSTRAP** environment variable to get the modern template (otherwise, you'll get the legacy template).

macOS/Linux

```
export CDK_NEW_BOOTSTRAP=1
cdk bootstrap --show-template
```

Windows

```
set CDK_NEW_BOOTSTRAP=1
powershell "cdk bootstrap --show-template | Out-File -encoding utf8 bootstrap-
template.yaml"
```

Any modifications you make must adhere to the [bootstrapping template contract \(p. 189\)](#).

Deploy your modified template as described in [the section called “Bootstrapping from the AWS CloudFormation template” \(p. 179\)](#), 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, including how it uses bootstrapping resources (for example, how it refers to assets stored in the bootstrap bucket).

The AWS CDK includes two stack synthesizers:

- `LegacyStackSynthesizer` can be used with either bootstrap template. (It requires only an Amazon S3 bucket, and both templates include one.)
- `DefaultStackSynthesizer` requires the modern bootstrap template. It includes capabilities for cross-account deployments and [CDK Pipelines](#) (p. 266) 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, the default behavior depends on whether the context key `@aws-cdk/core:newStyleStackSynthesis` is set, either in the AWS CDK app's

source code or in `cdk.json`. If it is set, synthesis uses a `DefaultStackSynthesizer`; otherwise, a `LegacyStackSynthesizer` is used. This is the usual way of choosing a synthesizer unless you have customized the bootstrap template.

The most important differences between the two built-in stack synthesizers are summarized here.

Feature	LegacyStackSynthesizer	DefaultStackSynthesizer
<b>Bootstrap stack</b>	Both legacy and modern bootstrap stack	Modern bootstrap stack only
<b>Deployments</b>	AWS CDK Toolkit deployments only	AWS CDK Toolkit and CDK Pipelines deployments
<b>Assets</b>	Uses AWS CloudFormation parameters to reference assets	Expects assets to be in a predictable location
<b>Docker image assets</b>	Creates Amazon ECR repository on demand	Pushes images to Amazon ECR repository provisioned by bootstrapping
<b>Roles</b>	Uses AWS CDK Toolkit's current permissions to deploy	Uses roles and permissions provisioned by bootstrapping to deploy
<b>Versioning</b>	Not supported	Confirms versions of bootstrapping resources via embedded AWS CloudFormation rule

## 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 below. 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`).

### Note

The `LegacyStackSynthesizer` does not offer any customization properties.

## 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), then, 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 privilege isolation benefits to having two different bootstrap stacks in a single account, so there is 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 modern 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 with the values of the AWS partition, account ID, and region 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 deploy 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 deploy 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 deploy 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 deploy 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-
${Qualifier}-cf-exec-role-${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 deploy 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 deploy 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-${Qualifier}-cf-exec-role-${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 deploy 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 deploy 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 deploy 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 deploy 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, the synthesizer needs to be told the ARNs for the roles you want to use. The roles are:

- 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. The permissions this role needs can be seen in the template.
- 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: that is, 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 to ensure that yours 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	KMS permissions are now implicit via 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.

Template version	AWS CDK version	Changes
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 environment, and has a <code>aws-cdk:bootstrap-role</code> tag as well.
9	1.135.0	Fixes S3 asset uploads from being rejected by commonly referenced encryption SCP.
10	1.139.0	ECR ScanOnPush is now enabled by default.
11	1.150.0	Adds policy allowing Lambda to pull from Amazon ECR repos so it survives rebootstrapping.
12	1.152.0	Adds support for experimental <b>cdk import</b> .

# 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, making it easy 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 very particular approach toward solving the problem at hand, and things work out best when you follow their lead.

## Tip

For more details on AWS CDK constructs, see [the section called "Constructs" \(p. 71\)](#).

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, and may 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. While the value of the AWS CDK's model is plain, sometimes you'll come upon a construct that's perfect for your needs—if only you could make a small (or large) tweak. For this reason, the AWS CDK provides ways to "break out" of the construct model, moving 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 never anticipated. 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 L23 classes available for the service, you can fall back to the automatically generated L1 constructs, which map 1:1 onto 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",
        // ...
    }
});
```

```
});
```

In the rare case where you want to define a resource that doesn't have a corresponding `CfnXxx` class, such as a new resource type that hasn't yet been published in the AWS CloudFormation resource specification, 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 a L2 construct is missing a feature or you are trying to work around an issue, you can modify the L1 construct that is 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"  
};
```

## 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, the only solution is to 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, so from another user's perspective 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 completely cover here, but the following links should get you started:

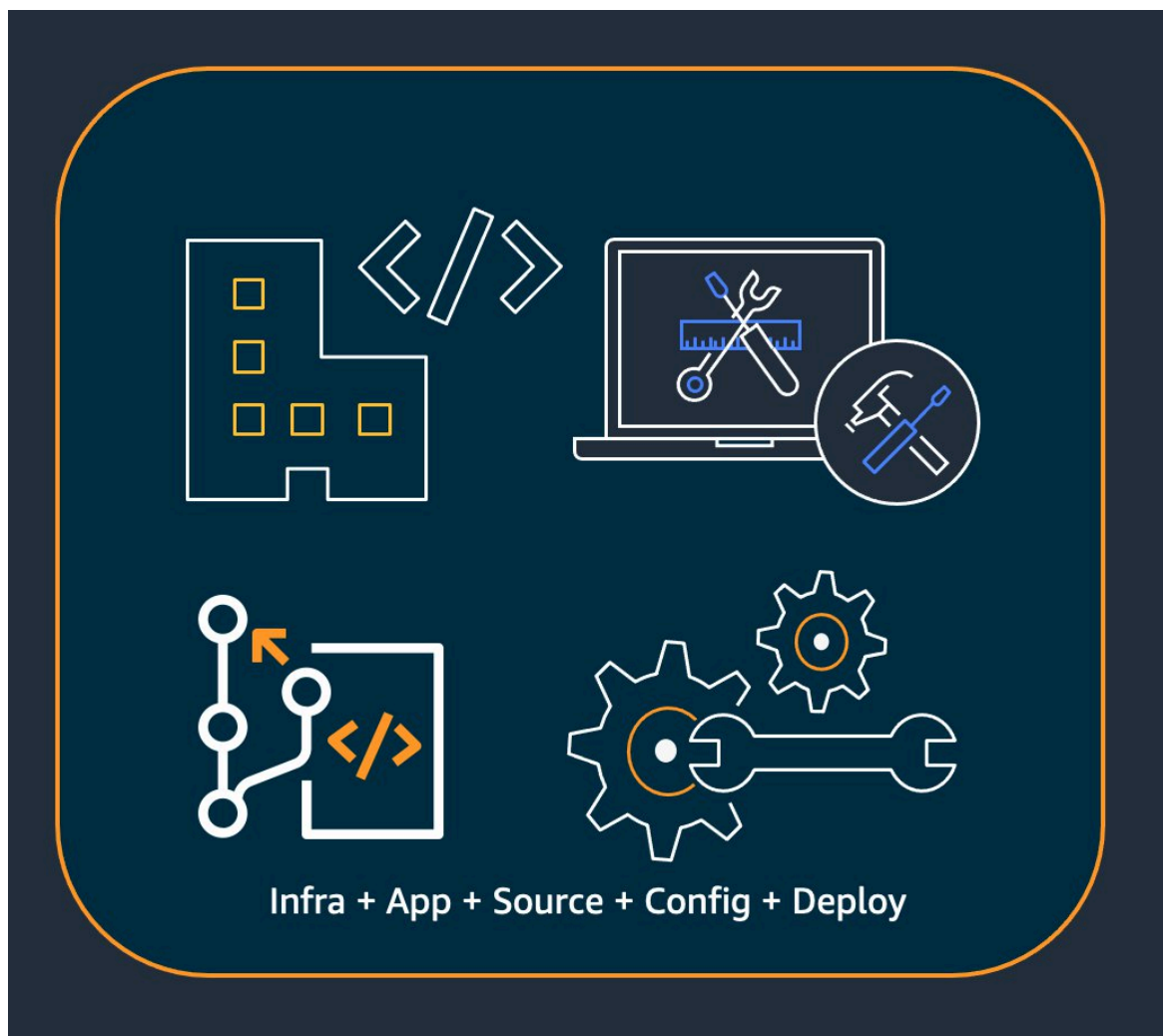
- [Custom Resources](#)
- [Custom-Resource Example](#)
- For a more fully fledged example, see the [DnsValidatedCertificate](#) class in the CDK standard library. This is implemented as a custom resource.

# Best practices for developing and deploying cloud infrastructure with the AWS CDK

The AWS CDK allows developers or administrators to define their cloud infrastructure 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 infrastructure (e.g. Amazon S3 buckets, Amazon RDS databases, Amazon VPC network), runtime code (e.g. AWS Lambda functions), and 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 \(p. 8\)](#).

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, such as configuration changes, that were not fully tested. Therefore, we developed the AWS CDK around a model in which your entire application, not just business logic but also infrastructure and configuration, is defined in code. 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 not only AWS CloudFormation templates describing your infrastructure in all target environments, but file assets containing 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” \(p. 202\)](#)
- [the section called “Coding best practices” \(p. 202\)](#)
- [the section called “Construct best practices” \(p. 204\)](#)
- [the section called “Application best practices” \(p. 206\)](#)

**Tip**

In addition to the guidance in this document, you should also consider [best practices for AWS CloudFormation](#) as well as for the individual AWS services you use, where they are obviously applicable to CDK-defined infrastructure.

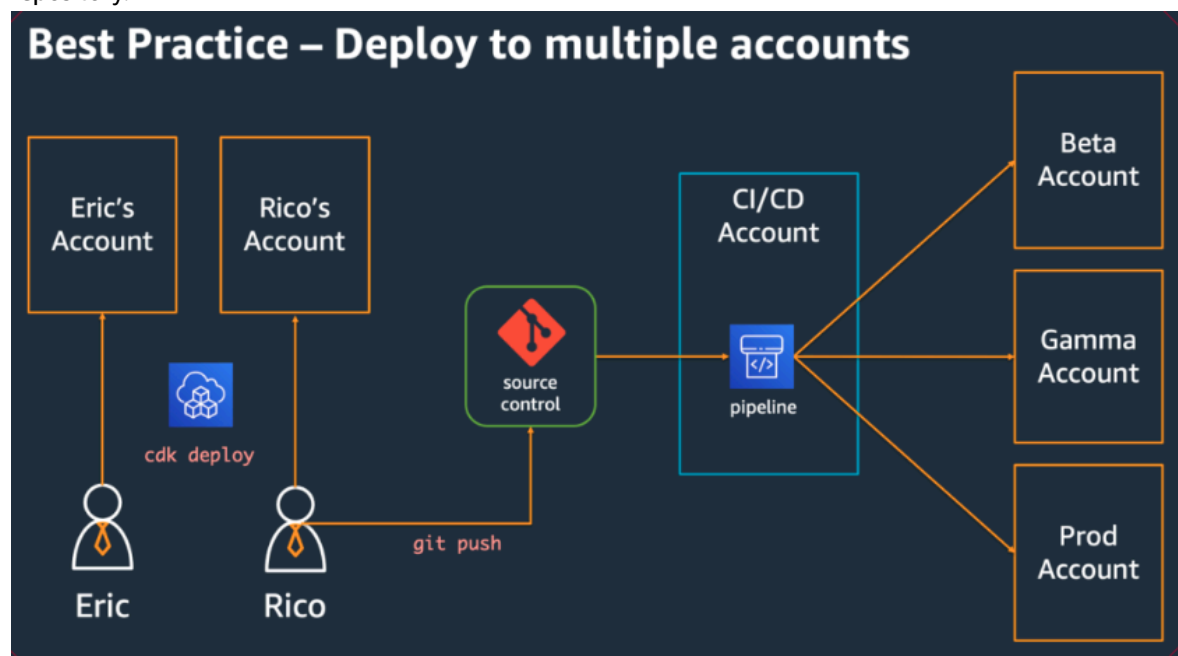
## Organization best practices

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 may 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 how cloud infrastructure will be done at your company, as well as for training and mentoring developers.

The CCoE may provide guidance on what programming languages should be used for cloud infrastructure. The details will vary from one organization to the next, but a good policy helps make sure developers can easily understand and maintain all cloud infrastructure throughout the company.

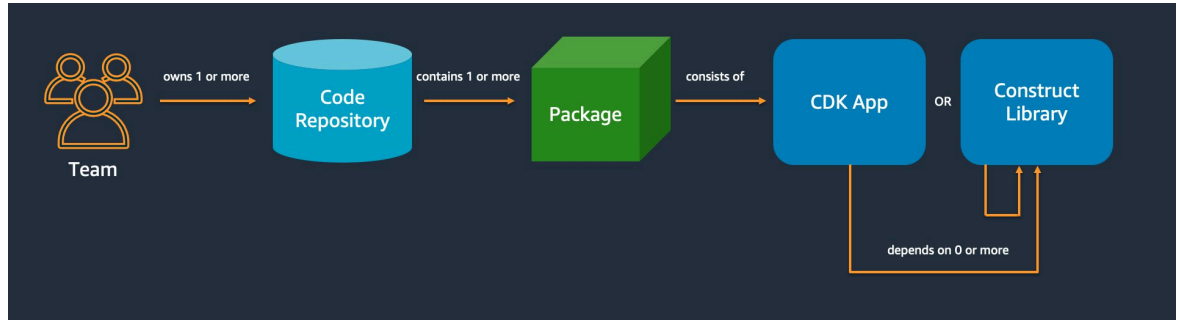
The CCoE also creates a "landing zone" that defines your organizational units within AWS. A landing zone is a pre-configured, secure, scalable, multi-account AWS environment based on best practice blueprints. You can tie together the services that make up your landing zone with [AWS Control Tower](#), a high-level service configures and manages your entire multi-account system from a single user interface.

Development teams should be able use their own accounts for testing and have the ability to 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. 266), 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 and/or account) 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 diagram below 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 always refactor your code as necessary to support new requirements, so it doesn't make sense to architect for all possible scenarios up front.

## 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. This is where you define how and where the different logical units of your application are deployed, as well as 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.

Though it is possible, it is not recommended to put multiple applications in the same repository, especially when using automated deployment pipelines, because this increases the "blast radius" of changes during deployment. With multiple applications in a repository, not only do changes to one application trigger deployment of the others (even if they have not changed), but 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, so they can be referenced by the build systems of the applications that use them, but updated on cadences independent of the lifecycles of those applications. It may make sense to put all shared constructs in one repository at first.

Also move packages to their own repo when different teams are working on them, to help enforce access control.

To consume packages across repository boundaries, you now need a private package repository—similar to NPM, PyPi, or Maven Central, but internal to your organization, and 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, for example NPM for TypeScript or JavaScript applications. Your package manager helps to make sure builds are repeatable by recording the specific versions of every package your application depends on and allows you to upgrade those dependencies in a controlled manner.

Shared packages need a different testing strategy: although for a single application it might be good enough to deploy the application to a testing environment and confirm that it still works, shared packages need to be tested independently of the consuming application, as if they were being released to the public. (Your organization might in fact 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

The AWS CDK not only generates AWS CloudFormation templates for deploying infrastructure, it also bundles runtime assets like Lambda functions and Docker images and deploys them alongside your infrastructure. So it's not only 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. These two kinds of code don't need to live in separate repositories or even in separate packages.

A construct that is self-contained, in other words that completely describes a piece of functionality including its infrastructure and logic, makes it easy to evolve the two kinds of code together, test them 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, and 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.

If one of your logical units is a Web site, for example, the constructs that make it up (Amazon S3 bucket, API Gateway, Lambda functions, Amazon RDS tables, etc.) should be composed into a single high-level construct, and 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 is 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. To do otherwise is to introduce a dependency on the machine that the code will run on, which becomes another bit of configuration information you have to keep track of and manage.

In general, environment variable lookups should be limited to the top level of an AWS CDK app, and should be used to pass in information needed for running in a development environment; see [the section called "Environments"](#) (p. 98).

## Unit test your infrastructure

If you avoid network lookups during synthesis and model all your production stages in code (best practices we cover later), you can run a full suite of unit tests at build time, consistently, in all environments. 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 how you expect them to. See [Testing constructs](#) (p. 312).

## 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 buckets, or persistent infrastructure like an Amazon VPC, this is almost never what you want. Be careful about any refactor of your AWS CDK code that could cause the ID to change, and 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; see [the section called "Logical IDs"](#) (p. 128).

## Constructs aren't enough for compliance

Many enterprise customers are writing their own wrappers for L2 constructs (the "curated" constructs that represent individual AWS resources with built-in sane defaults and best practices) to 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 it cannot be relied on 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. 174) 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 like these may prevent your developers from taking advantage of the growing ecosystems of AWS CDK packages, such as [AWS Solutions Constructs](#),

as these are typically built upon standard AWS CDK constructs and won't be able to use your custom versions.

## Application best practices

In this section we discuss how best 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 you can use, and the types of operations you can perform on them, are quite limited compared to those available in a general-purpose programming language.

Instead, try to make all decisions, such as which construct to instantiate, in your AWS CDK application, 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. Every name can only be used once, so if you hard-code 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, for example the `KeySchema` of an Amazon DynamoDB table, that property is immutable, and changing it requires a new resource. But the new resource must have the same name in order to be a true replacement, and it can't while the existing resource is still using that name.

A better approach is to specify as few names as possible. If you leave out resource names, the AWS CDK will generate them for you, and it'll do so in a way that won't cause these problems. You then, for example, pass the generated table name (which you can reference as `table.tableName` in your AWS CDK application) as an environment variable into your AWS Lambda function, or you generate a configuration file on your Amazon EC2 instance on startup, or you write the actual table name to AWS Systems Manager Parameter Store and your application reads it from there.

If the place you need it is another AWS CDK stack, that's even easier. Given one stack that defines the resource and another that needs to use it:

- If the two stacks are in the same AWS CDK app, just 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, `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 console. Or the second app can parse 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 does its best 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 to never delete the resource when it is removed from the stack, but rather orphan the resource 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 you don't actually need, and a corresponding AWS bill.

Consider carefully what you want these policies to actually be for each production resource and specify them accordingly. Use [the section called “Aspects” \(p. 174\)](#) 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 easier 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, and 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—so it makes sense not to nest them 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. A 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`.

You should 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 will 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? Here are just two of the 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, 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 may not be what you expected to happen.

These situations can be particularly pernicious because the AWS-side change may 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, allowing future synthesis operations produce exactly the same template. The only changes in the new template are the changes *you* made in your code. When you use a construct's `.fromLookup()` method, the result of the call is cached in `cdk.context.json`, which you should commit to version control along with the rest of your code to ensure 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" \(p. 167\)](#).

If you need some value (from AWS or elsewhere) for which there is no native CDK context provider, we recommend writing a separate script to 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

One of the great features of the AWS CDK construct library is the `grant()` convenience methods that allow quick and simple creation of AWS Identity and Access Management roles granting access to one resource by another using minimally-scoped permissions. For example, consider a line like the following:

```
myBucket.grantRead(myLambda)
```

This single line results in a policy being added 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, and 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, and your teams lose a lot of flexibility in how they design their applications. A better alternative is to use [service control policies](#) and [permission boundaries](#) to ensure 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 right into your source code. Create a stack for your production environment, and a separate one for each of your other stages, and put the configuration values for each right there 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, which 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, and that automation isn't possible without extensive amounts of monitoring. Create metrics, alarms, and dashboards to measure all aspects of your deployed resources. And don't just measure simple 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. It is organized by module.

Each module 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 generally 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, meaning that the code written in a previous version with the same major version can be upgraded to a newer version and be expected to continue to build and run, producing the same output.

### Note

This compatibility promise does not apply to APIs under active development, which are designated as experimental. See [the section called “AWS CDK stability index” \(p. 211\)](#) for more details.

## 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 may be, but is *not always*, compatible with construct libraries of a semantically *higher* version, depending 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, which may include releases of the AWS CDK Toolkit *older 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 simply 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 CDK stability index

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.

### Stage 0: CFN resources

All construct library modules start in stage 0 when they are auto-generated from the AWS CloudFormation resource specification. The goal of stage 0 is to make new AWS CloudFormation resources/properties available to AWS CDK customers as quickly as possible. We capture feedback from customers to better understand what L2 resources to add.

AWS CloudFormation resources themselves are considered stable APIs, regardless of whether other constructs in the module are under active development.

### Stage 1: Experimental

The goal of the experimental stage is to retain the freedom to make breaking changes to APIs while we design and build a module. During this stage, the primary use cases and the set of L2 constructs required to support them are incrementally identified, implemented, and validated.

Development of L2 constructs is community-oriented and transparent. For large and/or complex changes, we author a Request for Comments (RFC) that outlines our intended design and publish it for feedback. We also use pull requests to conduct API design reviews.

At this stage, individual APIs may be in flux, and breaking changes may occur from release to release if we deem these necessary to support customer use cases.

### Stage 2: Developer preview (DP)

At the developer preview stage, our aim is to deliver a release candidate with a stable API with which to conduct user acceptance testing. When the API passes acceptance, it is deemed suitable for general availability.

We make breaking changes at this stage only when required to address unforeseen customer use cases or issues. Since breaking changes are still possible, the package itself retains the "experimental" label while in developer preview.

### Stage 3: General availability (GA)

The module is generally available with a compatibility guarantee across minor versions. We will only make backward-compatible changes to the API, so that your existing apps will continue to work until the next major AWS CDK release.

In some cases, we may use [feature flags \(p. 173\)](#) to optionally enable new behavior while retaining the previous behavior to support existing apps.

Each module's Overview in the [API Reference](#) describes its stability level.

For more information about these maturity stages, see [AWS Construct Library Module Lifecycle](#).

## Language binding stability

From time to time, we may 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 may 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	Experimental

# Examples

This topic contains the following examples:

- [Creating a serverless application using the AWS CDK \(p. 213\)](#) Creates a serverless application using Lambda, API Gateway, and Amazon S3.
- [Creating an AWS Fargate service using the AWS CDK \(p. 226\)](#) 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 .env/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 above, you'll have trouble following the rest of the steps because some of the files the instructions tell you to modify aren't there (they'll 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.

```
/*
This code uses callbacks to handle asynchronous function responses.
It currently demonstrates using an async-await pattern.
AWS supports both the async-await and promises patterns.
For more information, see the following:
https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Statements/async\_function
https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Using\_promises
https://docs.aws.amazon.com/sdk-for-javascript/v2/developer-guide/calling-services-asynchronously.html
https://docs.aws.amazon.com/lambda/latest/dg/nodejs-prog-model-handler.html
*/
const AWS = require('aws-sdk');
const S3 = new AWS.S3();

const bucketName = process.env.BUCKET;

exports.main = async function(event, context) {
  try {
    var method = event.httpMethod;

    if (method === "GET") {
      if (event.path === "/" ) {
        const data = await S3.listObjectsV2({ Bucket: bucketName }).promise();
        var body = {
          widgets: data.Contents.map(function(e) { return e.Key })
        };
      }
    }
  }
}
```

```
        return {
            statusCode: 200,
            headers: {},
            body: JSON.stringify(body)
        };
    }
}

// We only accept GET for now
return {
    statusCode: 400,
    headers: {},
    body: "We only accept GET /"
};
} catch(error) {
    var body = error.stack || JSON.stringify(error, null, 2);
    return {
        statusCode: 400,
        headers: {},
        body: JSON.stringify(body)
    }
}
}
```

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

Add the API Gateway, Lambda, and Amazon S3 packages to the app.

### TypeScript

```
npm install @aws-cdk/aws-apigateway @aws-cdk/aws-lambda @aws-cdk/aws-s3
```

### JavaScript

```
npm install @aws-cdk/aws-apigateway @aws-cdk/aws-lambda @aws-cdk/aws-s3
```

### Python

```
pip install aws_cdk.aws_apigateway aws_cdk.aws_lambda aws_cdk.aws_s3
```

### Java

Add the following dependencies in the dependencies element of your project's pom.xml file.

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>apigateway</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>lambda</artifactId>
  <version>${cdk.version}</version>
</dependency>
```



```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>s3</artifactId>
  <version>${cdk.version}</version>
</dependency>
```

We recommend editing `pom.xml` directory rather than using your IDE's dependency management tools to make sure the versions of all AWS CDK libraries are synchronized using the `$cdk.version` variable.

## C#

Choose **Tools > NuGet Package Manager > Manage NuGet Packages for Solution** in Visual Studio and add the following packages.

```
Amazon.CDK.AWS.ApiGateway
Amazon.CDK.AWS.Lambda
Amazon.CDK.AWS.S3
```

### Tip

If you don't see these packages in the **Browse** tab of the **Manage Packages for Solution** page, make sure the **Include prerelease** checkbox is ticked.

For a better experience, also add the `Amazon.Jsii.Analyzers` package to provide compile-time checks for missing required properties.

Create a new source file to define the widget service with the source code shown below.

## TypeScript

File: `lib/widget_service.ts`

```
import * as core from "@aws-cdk/core";
import * as apigateway from "@aws-cdk/aws-apigateway";
import * as lambda from "@aws-cdk/aws-lambda";
import * as s3 from "@aws-cdk/aws-s3";

export class WidgetService extends core.Construct {
  constructor(scope: core.Construct, id: string) {
    super(scope, id);

    const bucket = new s3.Bucket(this, "WidgetStore");

    const handler = new lambda.Function(this, "WidgetHandler", {
      runtime: lambda.Runtime.NODEJS_14_X, // So we can use async in widget.js
      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 /  
  }  
}
```

## JavaScript

File: lib/widget\_service.js

```
const core = require("@aws-cdk/core");  
const apigateway = require("@aws-cdk/aws-apigateway");  
const lambda = require("@aws-cdk/aws-lambda");  
const s3 = require("@aws-cdk/aws-s3");  
  
class WidgetService extends core.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_14_X, // So we can use async in widget.js  
      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

```
from aws_cdk import (core,  
                      aws_apigateway as apigateway,  
                      aws_s3 as s3,  
                      aws_lambda as lambda_)  
  
class WidgetService(core.Construct):  
    def __init__(self, scope: core.Construct, id: str):  
        super().__init__(scope, id)  
  
        bucket = s3.Bucket(self, "WidgetStore")  
  
        handler = lambda_.Function(self, "WidgetHandler",  
                                   runtime=lambda_.Runtime.NODEJS_14_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.amazon.awscdk.core.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_14_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;

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_14_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 containing a lambda function, you must bootstrap your AWS environment. 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” \(p. 296\)](#). 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:

1. Opening the AWS Management Console.
2. Navigating to the API Gateway service.
3. Finding **Widget Service** in the list.
4. Selecting **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.

```
const AWS = require('aws-sdk');
```

```
const S3 = new AWS.S3();

const bucketName = process.env.BUCKET;

/*
This code uses callbacks to handle asynchronous function responses.
It currently demonstrates using an async-await pattern.
AWS supports both the async-await and promises patterns.
For more information, see the following:
https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Statements/async\_function
https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Using\_promises
https://docs.aws.amazon.com/sdk-for-javascript/v2/developer-guide/calling-services-asynchronously.html
https://docs.aws.amazon.com/lambda/latest/dg/nodejs-prog-model-handler.html
*/
exports.main = async function(event, context) {
  try {
    var method = event.httpMethod;
    // Get name, if present
    var 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.listObjectsV2({ Bucket: bucketName }).promise();
        var 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.getObject({ Bucket: bucketName, Key: widgetName }).promise();
        var 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();
      var data = widgetName + " created: " + now;

      var base64data = new Buffer(data, 'binary');

      await S3.putObject({
```

```
        Bucket: bucketName,
        Key: widgetName,
        Body: base64data,
        ContentType: 'application/json'
    }).promise();

    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.deleteObject({
        Bucket: bucketName, Key: widgetName
    }).promise();

    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
```

You should see a stack like the following, where `CDK-VERSION` is the version of the CDK and `NODE-VERSION` is the version of Node.js. (Your output may differ slightly from what's shown here.)

```
Resources:
  CDKMetadata:
    Type: AWS::CDK::Metadata
    Properties:
      Modules: aws-cdk=CDK-VERSION,@aws-cdk/core=CDK-VERSION,@aws-cdk/cx-api=CDK-VERSION,jsii-runtime=node.js/NODE-VERSION
```

## Add the Amazon EC2 and Amazon ECS packages

Install the AWS construct library modules for Amazon EC2 and Amazon ECS.

### TypeScript

```
npm install @aws-cdk/aws-ec2 @aws-cdk/aws-ecs @aws-cdk/aws-ecs-patterns
```

### JavaScript

```
npm install @aws-cdk/aws-ec2 @aws-cdk/aws-ecs @aws-cdk/aws-ecs-patterns
```

### Python

```
pip install aws_cdk.aws_ec2 aws_cdk.aws_ecs aws_cdk.aws_ecs_patterns
```

### Java

Using your IDE's Maven integration (e.g., in Eclipse, right-click your project and choose **Maven > Add Dependency**), install the following artifacts from the group `software.amazon.awscdk`:

```
ec2
ecs
ecs-patterns
```

## C#

Choose **Tools > NuGet Package Manager > Manage NuGet Packages for Solution** in Visual Studio and add the following packages.

```
Amazon.CDK.AWS.EC2
Amazon.CDK.AWS.ECS
```

Amazon.CDK.AWS.ECS.Patterns

### Tip

If you don't see these packages in the **Browse** tab of the **Manage Packages for Solution** page, make sure the **Include prerelease** checkbox is ticked.

For a better experience, also add the `Amazon.Jsii.Analyzers` package to provide compile-time checks for missing required properties.

## 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/aws-ec2";
import * as ecs from "@aws-cdk/aws-ecs";
import * as ecs_patterns from "@aws-cdk/aws-ecs-patterns";
```

### JavaScript

File: `lib/my_ecs_construct-stack.js`

```
const ec2 = require("@aws-cdk/aws-ec2");
const ecs = require("@aws-cdk/aws-ecs");
const ecs_patterns = require("@aws-cdk/aws-ecs-patterns");
```

### Python

File: `my_ecs_construct/my_ecs_construct_stack.py`

```
from aws_cdk import (core, 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

```
// Copyright 2010-2019 Amazon.com, Inc. or its affiliates. All Rights Reserved.
//
// This file is licensed under the Apache License, Version 2.0 (the "License").
// You may not use this file except in compliance with the License. A copy of the
// License is located at
//
// http://aws.amazon.com/apache2.0/
//
// This file is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS
// OF ANY KIND, either express or implied. See the License for the specific
// language governing permissions and limitations under the License.
import * as core from "@aws-cdk/core";
import * as ec2 from "@aws-cdk/aws-ec2";
import * as ecs from "@aws-cdk/aws-ecs";
import * as ecs_patterns from "@aws-cdk/aws-ecs-patterns";

export class MyEcsConstructStack extends core.Stack {
  constructor(scope: core.App, id: string, props?: core.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 true
    });
  }
}
```

#### JavaScript

```
// Copyright 2010-2019 Amazon.com, Inc. or its affiliates. All Rights Reserved.
//
// This file is licensed under the Apache License, Version 2.0 (the "License").
// You may not use this file except in compliance with the License. A copy of the
// License is located at
//
// http://aws.amazon.com/apache2.0/
//
// This file is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS
// OF ANY KIND, either express or implied. See the License for the specific
// language governing permissions and limitations under the License.
```

```
import * as core from "@aws-cdk/core";
import * as ec2 from "@aws-cdk/aws-ec2";
import * as ecs from "@aws-cdk/aws-ecs";
import * as ecs_patterns from "@aws-cdk/aws-ecs-patterns";

export class MyEcsConstructStack extends core.Stack {
  constructor(scope: core.App, id: string, props?: core.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 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 don'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 [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.

## 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” \(p. 134\)](#) 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” \(p. 234\)](#).

## 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 just as if they were defined in AWS CDK code, even using them within higher-level AWS CDK constructs, letting you use (for example) 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. You can use this capability to migrate your existing AWS CloudFormation templates to the AWS CDK a piece at a time in order to take advantage of the AWS CDK's convenient higher-level abstractions, or just to vend your AWS CloudFormation templates to AWS CDK developers by providing an AWS CDK construct API.

### Note

The AWS CDK also includes `core.CfnInclude`, which was previously used for the same general purpose. However, it lacks much of the functionality of `cloudformation-include.CfnInclude`.

## Install the `cloudformation-include` module

Follow these instructions to install the `cloudformation-include` module.

### TypeScript

```
npm install @aws-cdk/cloudformation-include
```

### JavaScript

```
npm install @aws-cdk/cloudformation-include
```

### Python

```
python -m pip install aws-cdk.cloudformation-include
```

### Java

Add the following to the `<dependencies>` container of `pom.xml`.

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
```

```
<artifactId>cdk-cloudformation-include</artifactId>
<version>${cdk.version}</version>
</dependency>
```

## C#

Right-click the project in Visual Studio's Solution Explorer and choose **Manage NuGet Packages**. Search for and install the package `Amazon.CDK.CloudFormation.Include`. Or change to your project's directory and issue:

```
dotnet add package Amazon.CDK.CloudFormation.Include
```

## Importing an AWS CloudFormation template

Here is a simple AWS CloudFormation template we'll 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, which you can obtain 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/core';
import * as cfninc from '@aws-cdk/cloudformation-include';

export class MyStack extends cdk.Stack {
  constructor(scope: cdk.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/core');
const cfninc = require('@aws-cdk/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

```
from aws_cdk import core
from aws_cdk import cloudformation_include as cfn_inc

class MyStack(core.Stack):

    def __init__(self, scope: core.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.core.Construct;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.StackProps;
import software.amazon.awscdk.cloudformation.include.CfnInclude;

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 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 for AWS CloudFormation to recognize these as the same resources from the AWS CloudFormation template.

If you are instead developing an AWS CDK construct wrapper for the template so it can be used by AWS CDK developers ("vending"), have the AWS CDK generate new resource IDs instead, so 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/core';  
import { MyStack } from '../lib/my-stack';  
  
const app = new cdk.App();  
new MyStack(app, 'MyStack');
```

### JavaScript

```
const cdk = require('@aws-cdk/core');
const { MyStack } = require('../lib/my-stack');

const app = new cdk.App();
new MyStack(app, 'MyStack');
```

### Python

```
from aws_cdk import core
from mystack.my_stack import MyStack

app = core.App()
MyStack(app, "MyStack")
```

### Java

```
import software.amazon.awscdk.core.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. Going forward, 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, if `lambdaFunc` is an AWS Lambda function, and you wish to grant it write access to the bucket, you can do so using the bucket's convenient `grantWrite()` method, without needing 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 example below, 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 just 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 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 you make to them will appear in the template generated from the AWS CDK stack. The code below, 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, and 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, and 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 which you can access the AWS CDK [NestedStack](#) instance via the `stack` property (as shown in the example) or 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 that 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. On the other hand, 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 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 simply 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](#)

The screenshot shows the AWS CloudFormation Registry console. On the left, there's a 'Filter' sidebar. Under 'Extension type', 'Resource types' is selected. Under 'Publisher', 'Third party' is selected. The main area is titled 'Extensions (1/26)' and has an 'Activate' button in the top right. A search bar is present with the placeholder 'Search by extension prefix (eg. AWS::S3)'. Below the search bar, there's a list of extensions. The first extension, 'AWSQS::EKS::Cluster', is highlighted. It is published by 'AWS Quick Start' and is a 'Verified AWS Marketplace publisher'. The description says: 'A resource that creates Amazon Elastic Kubernetes Service (Amazon EKS) clusters.' At the bottom of the card, it says 'Last updated 2021-06-21 16:58:53 UTC-0700 | Tested' and 'Not activated'.

1. Log 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. Click **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, or search for it, then activate the radio button in the upper right corner of the extension's card.
5. Click 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 may override the extension's default name, specify an execution role and logging configuration, and choose whether to automatically update the extension when a new version is released. When you have set these options as you like, click **Activate extension** at the bottom of the page.

To activate a third-party extension using the AWS CLI, use the `activate-type` command, substituting the ARN of the custom type you want to use for the one given.

```
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 `AWSQS::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, as shown below for the actual extensions.

## 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 core module.

For example, suppose 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 \(p. 128\)](#) 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 \(p. 250\)](#)).

## Reading Systems Manager values at deployment time

To read values from the Systems Manager Parameter Store, use the [valueForStringParameter](#) and [valueForSecureStringParameter](#) methods, depending on whether the attribute you want is a plain string or a secure string value. These methods return [tokens \(p. 128\)](#), 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/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/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, so that the resulting AWS CloudFormation template always uses the same value, rather than 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" \(p. 167\)](#) value. If the value is not already cached in `cdk.json` or passed on the command line, it will be 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, which may 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/aws-ssm';

const stringValue = ssm.StringParameter.valueFromLookup(this, 'my-plain-parameter-name');
```

### JavaScript

```
const ssm = require('@aws-cdk/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/aws-secretsmanager";

export class SecretsManagerStack extends core.Stack {
  constructor(scope: core.App, id: string, props?: core.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/aws-secretsmanager");

class SecretsManagerStack extends core.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(core.Stack):
    def __init__(self, scope: core.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 you can use with the above 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. 128). As it is a token, it has meaning only after resolution; your CDK app does not need to access its actual value, but can instead 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 other 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 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, and how to instantiate multiple stacks from this class. The example uses a Boolean property, named `encryptBucket` (Python: `encrypt_bucket`), to indicate 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 \(p. 8\)](#) 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.

Finally, install the `core` and `s3` AWS Construct Library modules. We use these modules in our app.

#### TypeScript

```
npm install @aws-cdk/core @aws-cdk/aws-s3
```

#### JavaScript

```
npm install @aws-cdk/core @aws-cdk/aws-s3
```

#### Python

```
pip install aws_cdk.core aws_cdk.aws_s3
```

#### Java

Using the Maven integration in your IDE (for example, in Eclipse, right-click the project and choose **Maven > Add Dependency**), add the following packages in the group `software.amazon.awscdk`.

```
core  
s3
```

#### C#

```
nuget install Amazon.CDK  
nuget install Amazon.CDK.AWS.S3
```

Or **Tools > NuGet Package Manager > Manage NuGet Packages for Solution** in Visual Studio

#### Tip

If you don't see these packages in the **Browse** tab of the **Manage Packages for Solution** page, make sure the **Include prerelease** checkbox is ticked. For a better experience, also add the `Amazon.Jsii.Analyzers` package to provide compile-time checks for missing required properties.

## Add optional parameter

The `props` argument of the `Stack` constructor fulfills the interface `StackProps`. Because we want our 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 that property. This allows the compiler to make sure 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 boldface.

#### TypeScript

File: `lib/multistack-stack.ts`

```
import * as cdk from '@aws-cdk/core';  
import * as s3 from '@aws-cdk/aws-s3';  
  
interface MultiStackProps extends cdk.StackProps {  
  encryptBucket?: boolean;  
}
```

```
export class MultistackStack extends cdk.Stack {
  constructor(scope: cdk.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/core');

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.

```
from aws_cdk import aws_s3 as s3

class MultistackStack(core.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: core.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, so we'll simply write our stack's constructor to accept an optional Boolean parameter. Since props is an optional argument, we'll write an additional constructor that allows you to skip it. It will default to false.

```
package com.myorg;

import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.StackProps;
import software.amazon.awscdk.core.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 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, 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 boldface.

TypeScript

File: lib/multistack-stack.ts

```
import * as cdk from '@aws-cdk/core';
import * as s3 from '@aws-cdk/aws-s3';
```

```
interface MultistackProps extends cdk.StackProps {
    encryptBucket?: boolean;
}

export class MultistackStack extends cdk.Stack {
    constructor(scope: cdk.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/core');
const s3 = require('@aws-cdk/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

```
from aws_cdk import core
from aws_cdk import aws_s3 as s3

class MultistackStack(core.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: core.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=core.RemovalPolicy.DESTROY)
    else:
        s3.Bucket(self, "MyGroovyBucket",
                  removal_policy=core.RemovalPolicy.DESTROY)
```

Java

File: src/main/java/com/myorg/MultistackStack.java

```
package com.myorg;

import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.StackProps;
import software.amazon.awscdk.core.Construct;
import software.amazon.awscdk.core.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 boldface 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/core';
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/core');  
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  
  
from aws_cdk import core  
  
from multistack.multistack_stack import MultistackStack  
  
app = core.App()  
MultistackStack(app, "MyWestCdkStack",  
                 env=core.Environment(region="us-west-1"),  
                 encrypt_bucket=False)  
  
MultistackStack(app, "MyEastCdkStack",  
                 env=core.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.core.App;  
import software.amazon.awscdk.core.Environment;  
import software.amazon.awscdk.core.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 a AWS CloudFormation template for `MyEastCdkStack`—the stack in `us-east-1`. This is the stack with the encrypted S3 bucket.

```
$ cdk synth MyEastCdkStack
```

The output should look similar to the following AWS CloudFormation template (there might be slight differences).

```
Resources:
  MyGroovyBucketFD9882AC:
    Type: AWS::S3::Bucket
    Properties:
      BucketEncryption:
        ServerSideEncryptionConfiguration:
          - ServerSideEncryptionByDefault:
              SSEAlgorithm: aws:kms
      UpdateReplacePolicy: Retain
      DeletionPolicy: Retain
    Metadata:
      aws:cdk:path: MyEastCdkStack/MyGroovyBucket/Resource
  CDKMetadata:
    Type: AWS::CDK::Metadata
    Properties:
      Modules: aws-cdk=1.10.0,@aws-cdk/aws-events=1.10.0,@aws-cdk/aws-iam=1.10.0,@aws-cdk/
aws-kms=1.10.0,@aws-cdk/aws-s3=1.10.0,@aws-cdk/core=1.10.0,@aws-cdk/cx-api=1.10.0,@aws-cdk/
region-info=1.10.0,jsii-runtime=node.js/v10.16.2
```

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 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's contents, but not the bucket itself, using the AWS Management Console or the AWS CLI before destroying the stack.

## 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 just don't need to pass in the metric, since 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” \(p. 167\)](#).

## 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 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 and/or stacks.

#### Note

CDK Pipelines supports two APIs: the original API that was made available in the Developer Preview, and a modern one 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 environment(s) to which you will deploy your stacks. An [environment \(p. 98\)](#) is an account/region pair to which you want to deploy a CDK stack. A CDK Pipeline involves at least two environments: the environment where the pipeline is provisioned, and the environment 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” \(p. 177\)](#) for more information on the kinds of resources created by bootstrapping and how to customize the bootstrap stack.

You may have already bootstrapped one or more environments so you can deploy assets and Lambda functions using the AWS CDK. Continuous deployment with CDK Pipelines requires that the CDK Toolkit

stack include additional resources, so the bootstrap stack has been extended to include an additional Amazon S3 bucket, an Amazon ECR repository, and IAM roles to give the various parts of a pipeline the permissions they need. This new style of CDK Toolkit stack will eventually become the default, but at this writing, you must opt in. The AWS CDK Toolkit will upgrade your existing bootstrap stack or create a new one, as necessary.

To bootstrap an environment that can provision an AWS CDK pipeline, set the environment variable `CDK_NEW_BOOTSTRAP` before invoking `cdk bootstrap`, as shown below. Invoking the AWS CDK Toolkit via the `npx` command installs it if necessary, and will 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 ensures 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 may omit the **--profile** option if your default AWS profile contains the necessary credentials or to instead use the environment variables `AWS_ACCESS_KEY_ID`, `AWS_SECRET_ACCESS_KEY`, and `AWS_DEFAULT_REGION` to provide your AWS account credentials.

macOS/Linux

```
export CDK_NEW_BOOTSTRAP=1
npx cdk bootstrap aws://ACCOUNT-NUMBER/REGION --profile ADMIN-PROFILE \
  --cloudformation-execution-policies arn:aws:iam::aws:policy/AdministratorAccess
```

Windows

```
set CDK_NEW_BOOTSTRAP=1
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 commands below instead. The **--trust** option indicates which other account should have permissions to deploy AWS CDK applications into this environment; specify the pipeline's AWS account ID.

Again, you may omit the **--profile** option if your default AWS profile contains the necessary credentials or if you are using the `AWS_*` environment variables to provide your AWS account credentials.

macOS/Linux

```
export CDK_NEW_BOOTSTRAP=1
cdk bootstrap aws://ACCOUNT-NUMBER/REGION --profile ADMIN-PROFILE \
  --cloudformation-execution-policies arn:aws:iam::aws:policy/AdministratorAccess \
  --trust PIPELINE-ACCOUNT-NUMBER
```

Windows

```
set CDK_NEW_BOOTSTRAP=1
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 old Amazon S3 bucket is orphaned when the new bucket is created. Delete it manually 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 CodeStar or AWS CodeCommit.)

```
git clone GITHUB-CLONE-URL my-pipeline
cd my-pipeline
```

### Note

You may use a name other than my-pipeline for your app's main directory, but since the AWS CDK Toolkit bases some file and class names on the name of the main directory, you'll need to tweak these later in this topic.

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 to 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.

Install the CDK Pipelines module along with any others you'll be using.

### 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" \(p. 167\)](#).

### TypeScript

```
npm install @aws-cdk/pipelines @aws-cdk/aws-lambda
```

### JavaScript

```
npm install @aws-cdk/pipelines @aws-cdk/aws-lambda
```

### Python

```
python -m pip install aws_cdk.pipelines aws_cdk.aws_lambda
```

Add the project's dependencies to `requirements.txt` so they can be installed in the CI/CD environment. It is convenient to use `pip freeze` for this.

### macOS/Linux

```
python -m pip freeze | grep -v '^[ -#]' > requirements.txt
```

### Windows

```
python -m pip freeze | findstr /R /B /V "[ -#]" > requirements.txt
```

### Java

Edit your project's `pom.xml` and add a `<dependency>` element for the pipeline module and the others you'll need. Follow the template below for each module, placing each inside the existing `<dependencies>` container.

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>cdk-pipelines</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>lambda</artifactId>
  <version>${cdk.version}</version>
</dependency>
```

After updating `pom.xml`, issue `mvn package` to install the new modules.

### C#

In Visual Studio, choose **Tools > NuGet Package Manager > Manage NuGet Packages for Solution** in Visual Studio and add the following packages.

```
Amazon.CDK.Pipelines
Amazon.CDK.AWS.Lambda
```

Finally, add the `@aws-cdk/core:newStyleStackSynthesis` [feature flag \(p. 173\)](#) to the new project's `cdk.json` file. The file will already contain some context values; add this new one inside the `context` object if it's not already there.

```
{
  ...
  "context": {
    ...
    "@aws-cdk/core:newStyleStackSynthesis": true
  }
}
```

In a future release of the AWS CDK, "new style" stack synthesis will become the default, but for now we need to opt in using the feature flag.

## 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 (e.g. a GitHub repository) and the commands to build the app. For example, the following defines a pipeline whose source is stored in a GitHub repository, and 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/core';
import { CodePipeline, CodePipelineSource, ShellStep } from '@aws-cdk/pipelines';

export class MyPipelineStack extends cdk.Stack {
  constructor(scope: cdk.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 'source-map-support/register';
```

```
import * as cdk from '@aws-cdk/core';
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/core');
const { CodePipeline, CodePipelineSource, ShellStep } = require('@aws-cdk/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/core');
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`):

```
from aws_cdk import core as cdk
from aws_cdk.pipelines import CodePipeline, CodePipelineSource, ShellStep

class MyPipelineStack(cdk.Stack):
```

```
def __init__(self, scope: cdk.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
from aws_cdk import core 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.amazon.awscdk.core.Construct;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.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.core.App;
import software.amazon.awscdk.core.Environment;
import software.amazon.awscdk.core.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 = "1111111111", Region = "eu-west-1" }
    });
    app.Synth();
  }
}
```

You must deploy a pipeline manually once. After that, the pipeline will keep itself up to date from the source code repository, so make sure 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, 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](#) (not to be confused with `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/core';
import { Function, InlineCode, Runtime } from '@aws-cdk/aws-lambda';

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

    new Function(this, 'LambdaFunction', {
      runtime: Runtime.NODEJS_12_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/core';  
import { MyLambdaStack } from './my-pipeline-lambda-stack';  
  
export class MyPipelineAppStage extends cdk.Stage {  
  constructor(scope: cdk.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/core';  
import { CodePipeline, CodePipelineSource, ShellStep } from '@aws-cdk/pipelines';  
import { MyPipelineAppStage } from './my-pipeline-app-stage';  
  
export class MyPipelineStack extends cdk.Stack {  
  constructor(scope: cdk.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/core');  
const { Function, InlineCode, Runtime } = require('@aws-cdk/aws-lambda');  
  
class MyLambdaStack extends cdk.Stack {  
  constructor(scope, id, props) {  
    super(scope, id, props);  
  
    new Function(this, 'LambdaFunction', {  
      runtime: Runtime.NODEJS_12_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/core');
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/core');
const { CodePipeline, CodePipelineSource, ShellStep } = require('@aws-cdk/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.

```
from aws_cdk import core as cdk
from aws_cdk.aws_lambda import Function, InlineCode, Runtime

class MyLambdaStack(cdk.Stack):
    def __init__(self, scope: cdk.Construct, construct_id: str, **kwargs) -> None:
        super().__init__(scope, construct_id, **kwargs)

        Function(self, "LambdaFunction",
            runtime=Runtime.NODEJS_12_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.

```
from aws_cdk import core as cdk
from my_pipeline.my_pipeline_lambda_stack import MyLambdaStack

class MyPipelineAppStage(cdk.Stage):
    def __init__(self, scope: cdk.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.

```
from aws_cdk import core as cdk
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: cdk.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.amazon.awscdk.core.Construct;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.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_12_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.amazon.awscdk.core.Construct;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.Stage;
import software.amazon.awscdk.core.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.amazon.awscdk.core.Construct;
import software.amazon.awscdk.core.Environment;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.StackProps;
import software.amazon.awscdk.core.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 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_12_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;

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 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/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/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 you are performing. Using the CDK Pipeline library's [ShellStep](#), you can try to access a just-deployed Amazon API Gateway backed by a Lambda function, for example, or issue an AWS CLI command to check some setting of a deployed resource.

In its simplest form, adding validation actions looks like this:

#### TypeScript

```
// stage was returned by pipeline.addStage  
  
stage.addPost(new ShellStep("validate", {  
    commands: ['curl -Ssf https://my.webservice.com/'],  
}));
```

#### JavaScript

```
// stage was returned by pipeline.addStage  
  
stage.addPost(new ShellStep("validate", {  
    commands: ['curl -Ssf https://my.webservice.com/'],  
}));
```

#### Python

```
# stage was returned by pipeline.add_stage  
  
stage.add_post(ShellStep("validate",  
    commands=['curl -Ssf https://my.webservice.com/']  
))
```

#### Java

```
// stage was returned by pipeline.addStage
```

```
stage.addPost(ShellStep.Builder.create("validate")
    .commands(Arrays.asList("curl -Ssf https://my.webservice.com/"))
    .build());
```

#### C#

```
// stage was returned by pipeline.addStage

stage.AddPost(new ShellStep("validate", new ShellStepProps
{
    Commands = new string[] { "curl -Ssf https://my.webservice.com/" }
}));
```

Because many AWS CloudFormation deployments result in the generation of resources with unpredictable names, 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 and 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 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=["curl -Ssf https://my.webservice.com/"],
))
```

### 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, but 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, as it has the ability to change the infrastructure that gets deployed.
- Use dependency locking to prevent accidental upgrades. CDK Pipelines respects `package-lock.json` and `yarn.lock` to ensure your dependencies are the ones you expect.
- 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. Eliminate 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 tools

This section contains information about the AWS CDK tools listed below.

## Topics

- [AWS CDK Toolkit \(cdk command\) \(p. 290\)](#)
- [AWS Toolkit for Visual Studio Code \(p. 311\)](#)
- [AWS SAM integration \(p. 311\)](#)

## 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@1.x      # install latest 1.x version
npm install -g aws-cdk@X.YY.Z   # install specific version
```

You may also use CDK Toolkit v2.x with CDK v1.x projects. An exception is that CDK Toolkit v2 creates CDK v2 projects. You cannot create CDK v1 projects while CDK Toolkit v2.x is installed globally; uninstall the global version and use **npx** to run the latest 1.x release.

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

### Tip

If you regularly work with multiple versions of the AWS CDK, you may want to install a matching version of the AWS CDK Toolkit in individual CDK projects. TypeScript and JavaScript projects have a local copy of the CDK Toolkit already. For other languages, omit `-g` from the `npm install` command. Then use `npx aws-cdk` to invoke **cdk**; this will run 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 the specified stack(s)

Command	Function
<code>cdk bootstrap</code>	Deploys the CDK Toolkit staging stack; see <a href="#">the section called “Bootstrapping”</a> (p. 177)
<code>cdk deploy</code>	Deploys the specified stack(s)
<code>cdk destroy</code>	Destroys the specified stack(s)
<code>cdk diff</code>	Compares the specified stack and its dependencies with the deployed stack(s) 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 “Toolkit reference”](#) (p. 304) or [the section called “Built-in help”](#) (p. 292).

## 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 whitespace 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, and to contact their users with important information.

### Note

Prior to version 1.93.0, the AWS CDK reported the names and versions of the modules loaded during synthesis, rather than 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:H4sIAND9SGAAzXKS5AMBAA0L1b2PdzBYnEAdio3Rglg1Y60zQi7u6TWL/
XKmNULxeQSOKwaPTBqrNhwEWU3hGHICzK0dWWFAxoL/Fd8mvk+QkS/0X6BdjnCdgM00QKWz
+AqqLDt2Y3YMnLYWwAAAA="
```

The `Analytics` property is a gzipped, base64-encoded, prefix-encoded list of the constructs present 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
}
```

## Specifying credentials and region

The CDK Toolkit needs to know your AWS account credentials and the AWS region into which you are deploying, not only for deployment operations but also to retrieve context values during synthesis. Together, your account and region make up the *environment*.

### Important

We strongly recommend against using your main AWS account for day-to-day tasks. Instead, create a user in IAM and use its credentials with the CDK.

Credentials and 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_ACCESS_KEY_ID`, `AWS_SECRET_ACCESS_KEY`, and `AWS_DEFAULT_REGION` environment variables. Always specify all three variables, not just one or two.
- A specific profile defined in the standard AWS config and credentials files, and specified using the `--profile` option on `cdk` commands.
- The `[default]` section of the standard AWS config and credentials files.

### Note

The standard AWS config and credentials files are located at `~/.aws/config` and `~/.aws/credentials` (macOS/Linux) or `%USERPROFILE%\.aws\config` and `%USERPROFILE%\.aws\credentials` (Windows).

The environment specified in your AWS CDK app using the stack's `env` property is used during synthesis to generate an environment-specific AWS CloudFormation template and during deployment to override the account or region specified by one of the above methods. For more information, see [the section called "Environments"](#) (p. 98).

If you have the AWS CLI installed, the easiest way to configure your account credentials and a default region is to issue the following command:

```
aws configure
```

Provide your AWS access key ID, secret access key, and default region when prompted. These values are written to the `[default]` section of the `config` and `credentials` files.

If you don't have the AWS CLI installed, you can manually create or edit the `config` and `credentials` files to contain default credentials and a default region, in the following format.

- In `~/.aws/config` or `%USERPROFILE%\.aws\config`

```
[default]
region=us-west-2
```

- In `~/.aws/credentials` or `%USERPROFILE%\.aws\credentials`

```
[default]
aws_access_key_id=AKIAI44QH8DHBEXAMPLE
aws_secret_access_key=je7MtGbClwBF/2Zp9Utk/h3yCo8nvbEXAMPLEKEY
```

Besides specifying AWS credentials 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.

- In ~/.aws/config or %USERPROFILE%\aws\config

```
[profile test]
region=us-east-1

[profile prod]
region=us-west-1
```

- In ~/.aws/credentials or %USERPROFILE%\aws\credentials

```
[profile test]
aws_access_key_id=AKIAI44QH8DHBEXAMPLE
aws_secret_access_key=je7MtGbClwBF/2Zp9Utk/h3yCo8nvbEXAMPLEKEY

[profile test]
aws_access_key_id=AKIAI44QH8DHBEXAMPLE
aws_secret_access_key=je7MtGbClwBF/2Zp9Utk/h3yCo8nvbEXAMPLEKEY
```

Always add named profiles to both the config and credentials files. The AWS CDK Toolkit does not fall back to using the region in the [default] section when the specified named profile is not found in the config file, as some other AWS tools do.

### Important

Do not name a profile default: that is, do not use a [profile default] section in either config or credentials.

### Note

Although the AWS CDK uses credentials from the same sources files as other AWS tools and SDKs, including the [AWS Command Line Interface](#), it may behave slightly differently from these tools. See [Setting credentials](#) for complete details on setting up credentials for the AWS SDK for JavaScript, which the AWS CDK uses under the hood.

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. Since the AWS CDK supports programs written in a variety of languages, 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, which 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, so 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 if you want to run your app via a command other than the one in `cdk.json`, you can 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 \(p. 266\)](#), the CDK Toolkit understands your stacks and stages as a hierarchy, and 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 "*"          # 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 takes into account dependencies between stacks when deciding

the order in which to process them. For example, if one stack uses a value produced by another (such as the ARN of a resource defined in the second stack), 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 that contain [assets](#) (p. 146), synthesize to large templates, or use [CDK Pipelines](#) (p. 266) require 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. 177) 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 do not explicitly specify an environment so they can be deployed anywhere, 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`, a Customer Master Key (CMK) will be created, which also incurs charges per environment.

### Note

Older versions of the modern template created a Customer Master Key by default. To avoid charges, re-bootstrap using `--no-bootstrap-customer-key`.

The CDK Toolkit supports two bootstrap templates: the modern template and the legacy template. The legacy template is the default, but the modern template is required by CDK Pipelines. For more information, see [the section called “Bootstrapping”](#) (p. 177).

### Important

The modern bootstrap template effectively grants the permissions implied by the `--cloudformation-execution-policies` to any AWS account in the `--trust` list, which by default will extend permissions to read and write to any resource in the bootstrapped account. Make sure to [configure the bootstrapping stack](#) (p. 181) with policies and trusted accounts 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
```



### Tip

If you have installed CDK Toolkit v2 globally, **cdk init** creates CDK v2 projects. To avoid this, see [the section called “CDK Toolkit v2 compatibility” \(p. 64\)](#).

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 \(p. 266\)](#) stacks, the CDK Toolkit displays stack names as paths according to their location in the pipeline hierarchy (e.g., PipelineStack, PipelineStack/Prod, PipelineStack/Prod/MyService, etc).

If your app contains many stacks, you can specify full or partial stack IDs of the stacks to be listed; see [the section called “Specifying stacks” \(p. 295\)](#).

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 (e.g. 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 the specified stack(s).

See `cdk synth --help` for all available options. A few of the most-frequently-used options are covered below.

## Specifying context values

Use the `--context` or `-c` option to pass [runtime context](#) (p. 167) 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 wish, you may 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 the specified stack(s) 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 below.

## Skipping synthesis

The **cdk deploy** command normally synthesizes your app's stacks before deploying to make sure the deployment reflects the latest version of your app. If you know that you haven't made any changes to your code since your last **cdk synth**, you may suppress the redundant synthesis step when deploying. Simply specify your project's `cdk.out` directory in the **--app** option.

```
cdk deploy --app cdk.out StackOne StackTwo
```

## Disabling rollback

One of AWS CloudFormation's marquee features is its ability to roll back changes so that deployments are atomic—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 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 just slows you down.

For this reason, the CDK Toolkit allows you to 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 a AWS CloudFormation changeset 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 and 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, and 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 will be combined into a single deployment, which will begin 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 proper), 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. 134) 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 by prefixing 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 version(s), or with a saved AWS CloudFormation template, and displays a list of changes.

```
Stack HelloCdkStack
IAM Statement Changes
#####
# # Resource # Condition # Effect # Action # Principal
#####
# + # ${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 stack(s) with the existing deployment:

```
cdk diff MyStack
```

To compare your app's stack(s) with a saved CloudFormation template:

```
cdk diff --template ~/stacks/MyStack.old MyStack
```

## Configuration (cdk.json)

Default values for many CDK Toolkit command-line flags may be stored in a project's `cdk.json` file or in the `.cdk.json` file in your user directory. Below 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 false, CDK does not add metadata to resources that use assets.	<b>--no-asset-metadata</b>

Key	Notes	CDK Toolkit option
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. 167)</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>--outputs-file</b>
outputsFile	The file to which AWS CloudFormation outputs from deployed stacks will be written (in JSON format).	<b>--outputs-file</b>
pathMetadata	If <code>false</code> , 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>

Key	Notes	CDK Toolkit option
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. 300)</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. 296)</a> ).	<b>--toolkit-bucket-name</b>
toolkitStackName	The name of the bootstrap stack (see <a href="#">the section called "Bootstrapping your AWS environment" (p. 296)</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. 299)</a> .	<b>--watch</b>

## Toolkit reference

This section provides a reference for the AWS CDK Toolkit derived from its help, first a general reference with the options available with all commands, then (in collapsible sections) specific references with options available only with specific subcommands.



Usage: `cdk -a <cdk-app> COMMAND`

Commands:

<code>cdk list [STACKS..]</code>	Lists all stacks in the app	[aliases: ls]
<code>cdk synthesize [STACKS..]</code>	Synthesizes and prints the CloudFormation template for this stack	[aliases: synth]
<code>cdk bootstrap [ENVIRONMENTS..]</code>	Deploys the CDK toolkit stack into an AWS environment	
<code>cdk deploy [STACKS..]</code>	Deploys the stack(s) named STACKS into your AWS account	
<code>cdk import [STACK]</code>	Import existing resource(s) into the given STACK	
<code>cdk watch [STACKS..]</code>	Shortcut for 'deploy --watch'	
<code>cdk destroy [STACKS..]</code>	Destroy the stack(s) named STACKS	
<code>cdk diff [STACKS..]</code>	Compares the specified stack with the deployed stack or a local template file, and returns with status 1 if any difference is found	
<code>cdk metadata [STACK]</code>	Returns all metadata associated with this stack	
<code>cdk acknowledge [ID]</code>	Acknowledge a notice so that it does not show up anymore	[aliases: ack]
<code>cdk notices</code>	Returns a list of relevant notices	
<code>cdk init [TEMPLATE]</code>	Create a new, empty CDK project from a template.	
<code>cdk context</code>	Manage cached context values	
<code>cdk docs</code>	Opens the reference documentation in a browser	[aliases: doc]
<code>cdk doctor</code>	Check your set-up for potential problems	

Options:

<code>-a, --app</code>	REQUIRED: command-line for executing your app or a cloud assembly directory (e.g. "node bin/my-app.js")	[string]
<code>--build</code>	Command-line for a pre-synth build	[string]
<code>-c, --context</code>	Add contextual string parameter (KEY=VALUE)	[array]
<code>-p, --plugin</code>	Name or path of a node package that extend the CDK features. Can be specified multiple times	[array]
<code>--trace</code>	Print trace for stack warnings	[boolean]
<code>--strict</code>	Do not construct stacks with warnings	[boolean]
<code>--lookups</code>	Perform context lookups (synthesis fails if this is disabled and context lookups need to be performed)	[boolean] [default: true]

<code>--ignore-errors</code>	Ignores synthesis errors, which will likely produce an invalid output <span>[boolean] [default: false]</span>
<code>-j, --json</code>	Use JSON output instead of YAML when templates are printed to STDOUT <span>[boolean] [default: false]</span>
<code>-v, --verbose</code>	Show debug logs (specify multiple times to increase verbosity) <span>[count] [default: false]</span>
<code>--debug</code>	Enable emission of additional debugging information, such as creation stack traces of tokens <span>[boolean] [default: false]</span>
<code>--profile</code>	Use the indicated AWS profile as the default environment <span>[string]</span>
<code>--proxy</code>	Use the indicated proxy. Will read from HTTPS_PROXY environment variable if not specified <span>[string]</span>
<code>--ca-bundle-path</code>	Path to CA certificate to use when validating HTTPS requests. Will read from AWS_CA_BUNDLE environment variable if not specified <span>[string]</span>
<code>-i, --ec2creds</code>	Force trying to fetch EC2 instance credentials. Default: guess EC2 instance status <span>[boolean]</span>
<code>--version-reporting</code>	Include the "AWS::CDK::Metadata" resource in synthesized templates (enabled by default) <span>[boolean]</span>
<code>--path-metadata</code>	Include "aws:cdk:path" CloudFormation metadata for each resource (enabled by default) <span>[boolean] [default: true]</span>
<code>--asset-metadata</code>	Include "aws:asset:*" CloudFormation metadata for resources that uses assets (enabled by default) <span>[boolean] [default: true]</span>
<code>-r, --role-arn</code>	ARN of Role to use when invoking CloudFormation <span>[string]</span>
<code>--staging</code>	Copy assets to the output directory (use <code>--no-staging</code> to disable, needed for local debugging the source files with SAM CLI) <span>[boolean] [default: true]</span>
<code>-o, --output</code>	Emits the synthesized cloud assembly into a directory (default: <code>cdk.out</code> ) <span>[string]</span>
<code>--notices</code>	Show relevant notices <span>[boolean]</span>
<code>--no-color</code>	Removes colors and other style from console output <span>[boolean] [default: false]</span>
<code>--version</code>	Show version number <span>[boolean]</span>
<code>-h, --help</code>	Show help <span>[boolean]</span>

If your app has a single stack, there is no need to specify the stack name

If one of `cdk.json` or `~/.cdk.json` exists, options specified there will be used as defaults. Settings in `cdk.json` take precedence.

## cdk list(ls)

```
cdk list [STACKS..]
```

Lists all stacks in the app

Options:

<code>-l, --long</code>	Display environment information for each stack [boolean] [default: false]
-------------------------	--

## cdk synthesize (synth)

`cdk synthesize [STACKS..]`

Synthesizes and prints the CloudFormation template for this stack

Options:

<code>-e, --exclusively</code>	Only synthesize requested stacks, don't include dependencies [boolean]
<code>--validation</code>	After synthesis, validate stacks with the "validateOnSynth" attribute set (can also be controlled with <code>CDK_VALIDATION</code> ) [boolean] [default: true]
<code>-q, --quiet</code>	Do not output CloudFormation Template to stdout [boolean] [default: false]

## cdk bootstrap

`cdk bootstrap [ENVIRONMENTS..]`

Deploys the CDK toolkit stack into an AWS environment

Options:

<code>-b, --bootstrap-bucket-name, --toolkit-bucket-name</code>	The name of the CDK toolkit bucket; bucket will be created and must not exist [string]
<code>--bootstrap-kms-key-id</code>	AWS KMS master key ID used for the SSE-KMS encryption [string]
<code>--bootstrap-customer-key</code>	Create a Customer Master Key (CMK) for the bootstrap bucket (you will be charged but can customize permissions, modern bootstrapping only) [boolean]
<code>--qualifier</code>	String which must be unique for each bootstrap stack. You must configure it on your CDK app if you change this from the default. [string]
<code>--public-access-block-configuration</code>	Block public access configuration on CDK toolkit bucket (enabled by default) [boolean]
<code>-t, --tags</code>	Tags to add for the stack (KEY=VALUE) [array] [default: []]
<code>--execute</code>	Whether to execute ChangeSet (--no-execute will NOT execute the ChangeSet) [boolean] [default: true]

<code>--trust</code>	The AWS account IDs that should be trusted to perform deployments into this environment (may be repeated, modern bootstrapping only) [array] [default: []]
<code>--trust-for-lookup</code>	The AWS account IDs that should be trusted to look up values in this environment (may be repeated, modern bootstrapping only) [array] [default: []]
<code>--cloudformation-execution-policies</code>	The Managed Policy ARNs that should be attached to the role performing deployments into this environment (may be repeated, modern bootstrapping only) [array] [default: []]
<code>-f, --force</code>	Always bootstrap even if it would downgrade template version [boolean] [default: false]
<code>--termination-protection</code>	Toggle CloudFormation termination protection on the bootstrap stacks [boolean]
<code>--show-template</code>	Instead of actual bootstrapping, print the current CLI's bootstrapping template to stdout for customization [boolean] [default: false]
<code>--toolkit-stack-name</code>	The name of the CDK toolkit stack to create [string]
<code>--template</code>	Use the template from the given file instead of the built-in one (use <code>--show-template</code> to obtain an example) [string]

## cdk deploy

`cdk deploy [STACKS..]`

Deploys the stack(s) named STACKS into your AWS account

Options:

<code>--all</code>	Deploy all available stacks [boolean] [default: false]
<code>-E, --build-exclude</code>	Do not rebuild asset with the given ID. Can be specified multiple times [array] [default: []]
<code>-e, --exclusively</code>	Only deploy requested stacks, don't include dependencies [boolean]
<code>--require-approval</code>	What security-sensitive changes need manual approval [string] [choices: "never", "any-change", "broadening"]
<code>--ci</code>	Force CI detection [boolean] [default: false]

<code>--notification-arns</code>	ARNs of SNS topics that CloudFormation will notify with stack related events [array]
<code>-t, --tags</code>	Tags to add to the stack (KEY=VALUE), overrides tags from Cloud Assembly (deprecated) [array]
<code>--execute</code>	Whether to execute ChangeSet ( <code>--no-execute</code> will NOT execute the ChangeSet) [boolean] [default: true]
<code>--change-set-name</code>	Name of the CloudFormation change set to create [string]
<code>-f, --force</code>	Always deploy stack even if templates are identical [boolean] [default: false]
<code>--parameters</code>	Additional parameters passed to CloudFormation at deploy time (STACK:KEY=VALUE) [array] [default: {}]
<code>-O, --outputs-file</code>	Path to file where stack outputs will be written as JSON [string]
<code>--previous-parameters</code>	Use previous values for existing parameters (you must specify all parameters on every deployment if this is disabled) [boolean] [default: true]
<code>--toolkit-stack-name</code>	The name of the existing CDK toolkit stack (only used for app using legacy synthesis) [string]
<code>--progress</code>	Display mode for stack activity events [string] [choices: "bar", "events"]
<code>--rollback</code>	Rollback stack to stable state on failure. Defaults to 'true', iterate more rapidly with <code>--no-rollback</code> or <code>-R</code> . Note: do <b>not</b> disable this flag for deployments with resource replacements, as that will always fail [boolean]
<code>--hotswap</code>	Attempts to perform a 'hotswap' deployment, which skips CloudFormation and updates the resources directly, and falls back to a full deployment if that is not possible. Do not use this in production environments [boolean]
<code>--watch</code>	Continuously observe the project files, and deploy the given stack(s) automatically when changes are detected. Implies <code>--hotswap</code> by default [boolean]
<code>--logs</code>	Show CloudWatch log events from all resources in the selected Stacks in the terminal. 'true' by default, use <code>--no-logs</code> to turn off. Only in effect if specified alongside the ' <code>--watch</code> ' option [boolean] [default: true]

## cdk destroy

`cdk destroy [STACKS..]`

Destroy the stack(s) named STACKS

Options:

<code>--all</code>	Destroy all available stacks [boolean] [default: false]
--------------------	---

<code>-e, --exclusively</code>	Only destroy requested stacks, don't include dependees	[boolean]
<code>-f, --force</code>	Do not ask for confirmation before destroying the stacks	[boolean]

## cdk diff

`cdk diff [STACKS..]`

Compares the specified stack with the deployed stack or a local template file, and returns with status 1 if any difference is found

Options:

<code>-e, --exclusively</code>	Only diff requested stacks, don't include dependencies	[boolean]
<code>--context-lines</code>	Number of context lines to include in arbitrary JSON diff rendering	[number] [default: 3]
<code>--template</code>	The path to the CloudFormation template to compare with	[string]
<code>--security-only</code>	Only diff for broadened security changes	[boolean] [default: false]
<code>--fail</code>	Fail with exit code 1 in case of diff	[boolean] [default: false]

## cdk init

`cdk init [TEMPLATE]`

Create a new, empty CDK project from a template.

Options:

<code>-l, --language</code>	The language to be used for the new project (default can be configured in ~/.cdk.json)	[string] [choices: "csharp", "fsharp", "go", "java", "javascript", "python", "typescript"]
<code>--list</code>	List the available templates	[boolean]
<code>--generate-only</code>	If true, only generates project files, without executing additional operations such as setting up a git repo, installing dependencies or compiling the project	[boolean] [default: false]

## cdk context

`cdk context`

Manage cached context values

Options:

<code>-e, --reset</code>	The context key (or its index) to reset	[string]
--------------------------	---	----------

`--clear`

Clear all context

[boolean]

## AWS Toolkit for Visual Studio Code

The [AWS Toolkit for Visual Studio Code](#) is an open source plug-in 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, including 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. This article illustrates the standard approach to testing AWS CDK apps using the AWS CDK's [assertions](#) module and popular test frameworks such as [Jest](#) for TypeScript and JavaScript or [Pytest](#) for Python.

There are two categories of tests 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, and are also useful when you're developing new features using test-driven development (write a test first, then make it pass by writing a correct implementation). Fine-grained assertions are the tests you'll write the most of.
- **Snapshot tests** test the synthesized AWS CloudFormation template against a previously-stored baseline template or "master." 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 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 a 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 construct libraries we'll need. (We'll also use the Amazon SNS module and the core AWS CDK library; there's no need to install these separately because they're dependencies of the ones we installed explicitly.) Don't forget to add your testing framework and the assertions module!

### TypeScript

```
mkdir state-machine && cd state-machine
cdk init --language=typescript
npm install @aws-cdk/aws-lambda @aws-cdk/aws-sns-subscriptions @aws-cdk/aws-stepfunctions
npm install --save-dev jest @types/jest @aws-cdk/assertions
```

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 outline below. 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 @aws-cdk/aws-lambda @aws-cdk/aws-sns-subscriptions @aws-cdk/aws-
stepfunctions
npm install --save-dev jest @aws-cdk/assertions
```

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 outline below. 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": {
    ...
    "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
python -m pip install aws_cdk.aws_lambda aws_cdk.aws_sns_subscriptions
aws_cdk.aws_stepfunctions
python -m pip install pytest aws_cdk.assertions
```

## 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**.)

Edit `pom.xml` to include the following dependencies.

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>assertions</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>cloudwatch</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>lambda</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>sns</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>sns-subscriptions</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>sqs</artifactId>
  <version>${cdk.version}</version>
</dependency>
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>stepfunctions</artifactId>
  <version>${cdk.version}</version>
</dependency>
```

Also add the following JUnit dependencies.

```
><dependency>
  <groupId>org.junit.jupiter</groupId>
  <artifactId>junit-jupiter-api</artifactId>
  <version>${junit.version}</version>
  <scope>test</scope>
</dependency>
<dependency>
  <groupId>org.junit.jupiter</groupId>
```

```
<artifactId>junit-jupiter-engine</artifactId>
<version>${junit.version}</version>
<scope>test</scope>
</dependency>
<dependency>
  <groupId>org.assertj</groupId>
  <artifactId>assertj-core</artifactId>
  <version>3.21.0</version>
  <scope>test</scope>
</dependency>
```

## 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.

Choose **Tools > NuGet Package Manager > Manage NuGet Packages for Solution** and add the following packages to both projects in the solution:

- `AWS.CDK.Assertions`
- `AWS.CDK.AWS.Lambda`
- `AWS.CDK.AWS.SQL`
- `AWS.CDK.AWS.SNS`
- `AWS.CDK.AWS.SNS.Subscriptions`
- `AWS.CDK.AWS.StepFunctions`

## The example stack

Here's the stack we'll be testing 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/core";
import * as sns from "@aws-cdk/aws-sns";
import * as sns_subscriptions from "@aws-cdk/aws-sns-subscriptions";
import * as lambda from "@aws-cdk/aws-lambda";
import * as sfn from "@aws-cdk/aws-stepfunctions";

export interface ProcessorStackProps extends cdk.StackProps {
  readonly topics: sns.Topic[];
}

export class ProcessorStack extends cdk.Stack {
```

```
constructor(scope: cdk.Construct, id: string, props: ProcessorStackProps) {
  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_14_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/core");
const sns = require("@aws-cdk/aws-sns");
const sns_subscriptions = require("@aws-cdk/aws-sns-subscriptions");
const lambda = require("@aws-cdk/aws-lambda");
const sfn = require("@aws-cdk/aws-stepfunctions");

class ProcessorStack extends cdk.Stack {
  constructor(scope, id, props) {
    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_14_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 = { ProcessorStack }
```

## Python

Place the following code in `state_machine/state_machine_stack.py`:

```
from typing import List

from aws_cdk import aws_lambda as lambda_
from aws_cdk import aws_sns as sns
from aws_cdk import aws_sns_subscriptions as sns_subscriptions
from aws_cdk import aws_stepfunctions as sfn
from aws_cdk import core as cdk

class ProcessorStack(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_14_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.amazon.awscdk.core.Construct;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.core.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 ProcessorStack extends Stack {
    public ProcessorStack(final Construct scope, final String id, final List<Topic>
topics) {
        this(scope, id, null, topics);
    }

    public ProcessorStack(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_14_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 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_14_X,
                Handler = "handler",
                Code = Code.FromAsset("./start-state-machine"),
                Environment = Collections.SingletonMap("STATE_MACHINE_ARN",
stateMachine.StateMachineArn)
            });
            stateMachine.GrantStartExecution(func);

            var subscription = new LambdaSubscription(func);
            foreach (var topic in Topics)
            {
                topic.AddSubscription(subscription);
            }
        }
    }
}
```

```
        {
            Runtime = Runtime.NODEJS_14_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 to not actually instantiate our stack, since 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 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/core";

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/core");

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

from aws_cdk import core 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.core.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 it up 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 code below 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 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 your tests have been 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 `ProcessorStack` 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, if you were writing a CDK app, you'd 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, less verbose, and helps make stacks used only in tests "look different" from stacks you intend to deploy.

### TypeScript

```
import { Capture, Match, Template } from "@aws-cdk/assertions";
import * as cdk from "@aws-cdk/core";
import * as sns from "@aws-cdk/aws-sns";
import { ProcessorStack } from "../lib/processor-stack";

describe("ProcessorStack", () => {
  test("synthesizes the way we expect", () => {
```

```
const app = new cdk.App();

// Since the ProcessorStack 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 ProcessorStack 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 ProcessorStack.
const processorStack = new ProcessorStack(app, "ProcessorStack", {
  topics: topics, // Cross-stack reference
});

// Prepare the stack for assertions.
const template = Template.fromStack(processorStack);

}
```

## JavaScript

```
const { Capture, Match, Template } = require("@aws-cdk/assertions");
const cdk = require("@aws-cdk/core");
const sns = require("@aws-cdk/aws-sns");
const { ProcessorStack } = require("../lib/processor-stack");

describe("ProcessorStack", () => {
  test("synthesizes the way we expect", () => {
    const app = new cdk.App();

    // Since the ProcessorStack 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 ProcessorStack 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 ProcessorStack.
    const processorStack = new ProcessorStack(app, "ProcessorStack", {
      topics: topics, // Cross-stack reference
    });

    // Prepare the stack for assertions.
    const template = Template.fromStack(processorStack);
```

## Python

```
from aws_cdk import aws_sns as sns
from aws_cdk import core as cdk
from aws_cdk.assertions import Template

from app.processor_stack import ProcessorStack

def test_synthesizes_properly():
    app = cdk.App()

    # Since the ProcessorStack 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 ProcessorStack 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 ProcessorStack.
processor_stack = ProcessorStack(
    app, "ProcessorStack", topics=topics # Cross-stack reference
)

# Prepare the stack for assertions.
template = Template.from_stack(processor_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.core.App;
import software.amazon.awscdk.core.Stack;
import software.amazon.awscdk.services.sns.Topic;

import java.util.*;

import static org.assertj.core.api.Assertions.assertThat;

public class ProcessorStackTest {
    @Test
    public void testSynthesizesProperly() {
        final App app = new App();

        // Since the ProcessorStack 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
        // ProcessorStack 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 ProcessorStack.
        final ProcessorStack processorStack = new ProcessorStack(
            app,
            "ProcessorStack",
            topics // Cross-stack reference
        );

        // Prepare the stack for assertions.
        final Template template = Template.fromStack(processorStack)
```

#### 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 ProcessorStackTest
    {
        [TestMethod]
        public void TestMethod1()
        {
            var app = new App();

            // Since the ProcessorStack 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 ProcessorStack 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 ProcessorStack.
            var processorStack = new StateMachineStack(app, "ProcessorStack", new
            StateMachineStackProps
            {
                Topics = topics
            });

            // Prepare the stack for assertions.
            var template = Template.FromStack(processorStack);

            // 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(processorStack);

// 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, and these 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 the very lenient (`Match.anyValue`) to the quite strict (`Match.objectEquals`), and 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: {
      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 our initial state is the `only` step, again using 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 --
we can't provide
                        { "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.

For example, this example tests to make sure that the starting state of our state machine has a name beginning with `Start` and also that this state is actually 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 master. This isn't useful in catching regressions, as fine-grained assertions are, because it applies to the entire template, and things besides code changes can cause small (or not-so-small) differences in synthesis results. For example, we may update a CDK construct to incorporate a new best practice, which can cause changes to the synthesized resources or how they're organized, or we might update the CDK Toolkit to report 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 a new master and proceed.

For example, if we have this `DeadLetterQueue` construct:

TypeScript

```
import * as cloudwatch from '@aws-cdk/aws-cloudwatch';
import * as sqs from '@aws-cdk/aws-sqs';
import { Construct, Duration } from '@aws-cdk/core';
```

```
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

```
const cloudwatch = require('@aws-cdk/aws-cloudwatch');
const sqs = require('@aws-cdk/aws-sqs');
const { Construct, Duration } = require('@aws-cdk/core');

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: cdk.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

```
package software.amazon.samples.awscdkassertionssamples;

import org.jetbrains.annotations.NotNull;
import software.amazon.awscdk.services.cloudwatch.Alarm;
import software.amazon.awscdk.services.cloudwatch.IAlarm;
import software.amazon.awscdk.services.sqs.Queue;
import software.constructs.Construct;
```

```
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#

```
using Amazon.CDK;
using Amazon.CDK.AWS.SQS;
using Amazon.CDK.AWS.CloudWatch;

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/assertions";
import * as cdk from "@aws-cdk/core";
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/assertions");
const cdk = require("@aws-cdk/core");
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

```
from aws_cdk import core as cdk
from aws_cdk.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.core.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 ProcessorStackTest

    [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 be read and modified just as often, so it pays to take a moment to consider how best to write them. Don't copy and paste setup lines or common assertions, for example; 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 exactly 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. 337)
- [Compliance validation for the AWS Cloud Development Kit \(AWS CDK\)](#) (p. 338)
- [Resilience for the AWS Cloud Development Kit \(AWS CDK\)](#) (p. 338)
- [Infrastructure security for the AWS Cloud Development Kit \(AWS CDK\)](#) (p. 339)

## Identity and access management for the AWS Cloud Development Kit (AWS CDK)

AWS Identity and Access Management (IAM) is an Amazon Web Services (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 resources in AWS services. IAM is an AWS service that you can use with no additional charge.

To use the AWS CDK to access AWS, you need an AWS account and AWS credentials. To increase the security of your AWS account, we recommend that you use an *IAM user* to provide access credentials instead of using your AWS account credentials.

For details about working with IAM, see [AWS Identity and Access Management](#).

For an overview of IAM users and why they are important for the security of your account, see [AWS Security Credentials](#) in the [Amazon Web Services General Reference](#).

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](#).

## 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.
- [Architecting for HIPAA Security and Compliance Whitepaper](#) – A whitepaper that describes how companies can use AWS to create HIPAA-compliant applications.
- [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, code that used to work fine now results in errors \(p. 340\)](#)
- [After updating the AWS CDK, the AWS CDK Toolkit \(CLI\) reports a mismatch with the AWS Construct Library \(p. 342\)](#)
- [When deploying my AWS CDK stack, I receive a NoSuchBucket error \(p. 343\)](#)
- [When deploying my AWS CDK stack, I receive a forbidden: null message \(p. 343\)](#)
- [When synthesizing an AWS CDK stack, I get the message --app is required either in command-line, in cdk.json or in ~/.cdk.json \(p. 343\)](#)
- [When synthesizing an AWS CDK stack, I receive an error because the AWS CloudFormation template contains too many resources \(p. 344\)](#)
- [I specified three \(or more\) Availability Zones for my EC2 Auto-Scaling Group or Virtual Private Cloud, but it was only deployed in two \(p. 345\)](#)
- [My S3 bucket, DynamoDB table, or other resource is not deleted when I issue `cdk destroy` \(p. 345\)](#)

## After updating the AWS CDK, code that used to work fine now results in errors

Errors in code that used to work is typically a symptom of having mismatched versions of AWS Construct Library modules. Make sure all library modules are the same version and up-to-date.

An error message commonly seen in this situation is `unable to determine cloud assembly output directory`. Assets must be defined indirectly within a "Stage" or an "App" scope.

The modules that make up the AWS Construct Library are a matched set. They are released together and are intended to be used together. Interfaces between modules are considered private; we may change them when necessary to implement new features in the library.

We also update the libraries that are used by the AWS Construct Library from time to time, and different versions of the library modules may have incompatible dependencies. Synchronizing the versions of the library modules will also address this issue.

[JSII](#) is an important AWS CDK dependency, especially if you are using the AWS CDK in a language other than TypeScript or JavaScript. You do not ordinarily have to concern yourself with the JSII versions, since it is a declared dependency of all AWS CDK modules. If a compatible version is not installed, however, you can see unexpected type-related errors, such as `'undefined' is not a valid TargetType`. Making sure all AWS CDK modules are the same version will resolve JSII compatibility issues, since they will all depend on the same JSII version.

Below, you'll find details on managing the versions of your installed AWS Construct Library modules in TypeScript, JavaScript, Python, Java, and C#.

### TypeScript/JavaScript

Install your project's AWS Construct Library modules locally (the default). Use npm to install the modules and keep them up to date.

To see what needs to be updated:

```
npm outdated
```

To actually update the modules to the latest version:

```
npm update
```

If you are working with a specific older version of the AWS Construct Library, rather than the latest, first uninstall all of your project's `@aws-cdk` modules, then reinstall the specific version you want to use. For example, to install version 1.9.0 of the Amazon S3 module, use:

```
npm uninstall @aws-cdk/aws-s3
npm install @aws-cdk/aws-s3@1.9.0
```

Repeat these commands for each module your project uses.

You can edit your `package.json` file to lock the AWS Construct Library modules to a specific version, so `npm update` won't update them. You can also specify a version using `~` or `^` to allow modules to be updated to versions that are API-compatible with the current version, such as `^1.0.0` to accept any update API-compatible with version 1.x. Use the same version specification for all AWS Construct Library modules within a project, including these special characters. Otherwise, Node.js may not resolve all these specifications to the same concrete version, resulting in a mismatch.

## Python

Use a virtual environment to manage your project's AWS Construct Library modules. For your convenience, `cdk init` creates a virtual environment for new Python projects in the project's `.venv` directory.

Add the AWS Construct Library modules your project uses to its `requirements.txt` file. Use the `=` syntax to specify an exact version, or the `~=` syntax to constrain updates to versions without breaking API changes. For example, the following specifies the latest version of the listed modules that are API-compatible with version 1.x:

```
aws-cdk.core~=1.0
aws-cdk.aws-s3~=1.0
```

If you wanted to accept only bug-fix updates to, for example, version 1.9.0, you could instead specify `~=1.9.0`. Use the same version specification for all AWS Construct Library modules within a single project.

Use `pip` to install and update the modules.

To see what needs to be updated:

```
pip list --local --outdated
```

To actually update the modules to the latest compatible version:

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

If your project requires a specific older version of the AWS Construct Library, rather than the latest, first uninstall all of your project's `aws-cdk` modules. Edit `requirements.txt` to specify the exact versions of the modules you want to use using `=`, then install from `requirements.txt`.

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

## Java

Add your project's AWS Construct Library modules as dependencies in your project's `pom.xml`. You may specify an exact version, or use Maven's [range syntax](#) to specify a range of allowable versions.

For example, to specify an exact version of a dependency:

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>s3</artifactId>
  <version>1.23.0</version>
</dependency>
```

To specify that any 1.x.x version is acceptable (note use of right parenthesis to indicate that the end of the range excludes version 2.0.0):

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>s3</artifactId>
  <version>[1.0.0,2.0.0)</version>
</dependency>
```

Maven automatically downloads and installs the latest versions that allow all requirements to be fulfilled when you build your application.

If you prefer to pin dependencies to a specific version, you can issue `mvn versions:use-latest-versions` to rewrite the version specifications in `pom.xml` to the latest available versions when you decide to upgrade.

## C#

Use the Visual Studio NuGet GUI (**Tools > NuGet Package Manager > Manage NuGet Packages for Solution**) to install the desired version of your application's AWS Construct Library modules.

- The **Installed** panel shows you what modules are currently installed; you can install any available version of any module from this page.
- The **Updates** panel shows you modules for which updates are available, and lets you update some or all of them.

([back to list \(p. 340\)](#))

### 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 AWS Construct Library. The Toolkit is intended to be backward compatible within the same major version; the latest 1.x version of the toolkit can be used with any 1.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, for some reason, you need to work with multiple versions of the AWS CDK Toolkit, you can install a specific version of the toolkit locally in your project folder.

If you are using a language other than TypeScript or JavaScript, first create a `node_modules` folder in your project directory. Then, regardless of language, use `npm` to install the AWS CDK Toolkit, omitting the `-g` flag and specifying the desired version. For example:

```
npm install aws-cdk@1.50.0
```

To run a locally-installed AWS CDK Toolkit, use the command `npx aws-cdk` rather than just `cdk`. For example:

```
npx aws-cdk deploy MyStack
```

`npx aws-cdk` runs the local version of the AWS CDK Toolkit if one exists, and 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 or batch file to make sure `cdk` is always invoked this way. For example, Linux users might add the following statement to their `.bash_profile` file.

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

[\(back to list \(p. 340\)\)](#)

### When deploying my AWS CDK stack, I receive a `NoSuchBucket` error

Your AWS environment does not have a staging bucket, which the AWS CDK uses to hold resources during deployment. Stacks require this bucket if they contain [the section called “Assets” \(p. 146\)](#) or synthesize to AWS CloudFormation templates larger than 50 kilobytes. You can create the staging bucket with the following command:

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

To avoid generating unexpected AWS charges, the AWS CDK does not automatically create a staging bucket. You must bootstrap your environment explicitly.

By default, the staging bucket is created in the region(s) used by stacks in the current AWS CDK application, or 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
```

You must bootstrap in every region where you will deploy stacks that require a staging bucket.

For more information, see [the section called “Bootstrapping” \(p. 177\)](#)

[\(back to list \(p. 340\)\)](#)

### When deploying my AWS CDK stack, I receive a `forbidden: null` message

You are deploying a stack that requires the use of a staging bucket, 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 resource `arn:aws:s3:::cdktoolkit-stagingbucket-*`.

[\(back to list \(p. 340\)\)](#)

### 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 \(p. 340\)\)](#)

### **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” \(p. 226\)](#), for example, generates more than fifty 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 \(p. 107\)](#), so it is straightforward to 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 \(p. 97\)](#) construct.

[\(back to list \(p. 340\)\)](#)

### I specified three (or more) Availability Zones for my EC2 Auto-Scaling Group or Virtual Private Cloud, but it was only deployed in two

To get the number of Availability Zones you requested, 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, such that it can be deployed to any region. 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 never uses 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 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" \(p. 98\)](#).

[\(back to list \(p. 340\)\)](#)

### 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, 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/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,
    });
  }
}
```

## 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
    });
  }
}

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)
```

## 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).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 \(p. 340\)\)](#)

# 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+Y1ls1A+gnpw9FmLcZ1qkC9KLnS2MqvuxWLB
t3z4kjZaL9fQ+58PoD4gy/M2hDg6gZrYqR3gtJuw8FcFpb/1KlkzRQUM8eAMFxf2
TyfjP0V0tSHwCB+84oushX7fUXVMyc3+OHsCPOe/WBFMI1WgKA+n33JKIq1UUC8f
kCWBAsAFupil01CveT6mZu5s1NR1c1I3iBLjUZ3/MtLygfqAMKwUVXeaWtDvRIZe
PrAfC2Ny0DEhly2JG6K0FW7eIcvBqR3rg8U49t9Y74ELTM0kKnfd+flvq35xWqQC
0zghnk3kDppRTN4zWBgTKiCMxBcsHXG0oGn57t4B9VY9Zy3vkeySigeiwl/Tw9nJ
PE0SRnwEc/HnjTTFX+GTG1aQVE0xSVyZ4m5ymRNCu6+rNH81Kwo5FujlXJ+GXPkp
qT+Lx6Ix/Ny7PaoweWxwtZUKLRS4pWUsg0yotZrGyIbS+X3yMEG8WBTfI9hf6HTq
0ryfi5/TsBrdrGKqWB99EC9xYEGgtHp4fK05X0yn0agV0hf0jSe8t1uyuJPGB2Gc
MQagSys5xMhdG/ZnEY4Cb+JDtH/4jc3tca0+4Z5RQ7kF9IhCncFtrbjJbwARAQAB
tC5BV1MgQ2xvdWQgRGV2ZWxvcG11bnQsZ2l0IDxhd3MtY2RrQGFTYXpvi5jb20+
iQI/BBMBAgApBQJixIDrAhsVBQkHhM4ABwsJCAcDAgEGFQgCCQoLBBYCawECHgEC
F4AACGkQrnpIobNmHo2qg//Zt9p/kN1DevflzxWkouUX0AS7UmUtRYXu5k/EEbu
wkYNHUr7+lZ+Me5YyjcIpt6UuwG9cW4SvwuxIfXucyKAWiWbEbydCQauvnrYDxDa
J6Yr/ntk7Sii6An9re99qic3IsVx+xlUXh+qJ/34ooP/1PHziCMqykvW/DwAIyhx
2qvTXy+9+01OWSUBhkCnNz5XKb4XQGq73Dqa1ZX1nH4dG6fckZmYRX+dpw2njfTw
ZldZ7bkrfiL84FI4A21RfSbEU4s4ngiV17LZ9ivi1BKtBdv3da7+yc919M7C5N4J
yrlxvtyYND0qKAD2WYZAnpEbG/shu3f56Ry0Jd56tXGw19nKPh+F9y+379XthSwA
xZTURFtjWf7wWHaDZadU0DKi+Oeeszjg2f/VJaGmmS8PIg7q6GiSHHpqHqNvACHm
ZXMw12QFd3qt3xu0JmME11ZC5VBgblwpkQT004Sq1r0pJwXI90DMS/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
AVLlxG1unW34NlkKZbcbR86gAxRnnAhuEhPuloU/S5wAqPGBRiF158YjYZDNJw6U
1SSMpE401sfjxv9yAbiRihLYtvksyHHZmaDhYner2aK1PdeWu+BKq/tjfm3Yzsd2
uuVEdUJ72YoQk/29dEiG0HfT+2kUKxUX+0tJSJ9MG1Ef4NtQE4WLzrT6Xqb2SG4+
a1IiIVxIEi0XKDN7n8ZLjFwfJw0YxVYLtEUKqFWM8e8vgoc9/nYc+vDXZVED2g3Z
FWrwSnDSXbQpnMa2cLhD4xLpDHUS3i2p7r3dkJQGLo/5JG0opLibr0AbYZ72izhu
H/TuPFogSz0mNFPglrWdnLF04UIjIq420+06V4WQZC9n55Zjcbki/0hnC3B9pAdU
tiy8zg070bWq45dPGf5STkPPn7G8A2zmKefy051iLi26ZzW78siB+FvcGRhdg25
39sHJ1cmrTeC+B+k4KeV5sQ/m3UuccimrZnk1xdaiVp8mWzRqWb8bB6Rs8K9RMrMV
tFB0KOBAT2Qx0QtRGAantVgm193E1T1cmNpD0FKAKkDdPs64rKBEwFiHxccXHbah
eMdlweVvn3AKFD6uAm8ZRMV+dyssfcQxqpo/kFT1XpA6cQe0mGD0cKBfdwARAQAB
tCNBV1MgS1NjSSBUZWFtIDxhd3MtannPaUBhbWV6b24uY29tPokCPwQTAQIAKQUC
YsSA6QIbLwUJB4TOAACLCQgHAWIBBhUIAgkKCwQWAgMBAh4BAheAAoJEAVsThXa
49jZjU4QANoyq0JUT4gRrXshE3N0mW5Ad4i8Ke09GA62HyvTtfbsA+2nkNVGJpXm
sFMZdaF095Q65RkLS9vW4nhhjXBEC2XYNct2AnARudA/41ykjDPwU112z9ZTB9he
y4ItIeNGpHvMwr51fihl0y2nkp0D0Beiv44jScLbHyOmZfki1f5fuIu2U2IbUGK3
5FtYyeHcgRHnpYkzLuzK4Pfay0ywqQPJ7M9DWrHf+v5Cu4ZCZD0IKfzF+ew7MWwc
6KaoWHCYbFpX8jxFppbGsSF0Q8S12quoP0TLz9Wsq70KHi6C2P8JI6lM0HRL0+1M
jFbQxN0wAcN3k4HSwunAjXB1mT/6oc1RsdBdpXBaz2AWseIXwSYZqNXp+5L179uZ
vSiD3DSSUqLJbdQRV0sJi3/87V5QU59byq2dToHverjtsbVnK0TkTx9Z1gkcpjvM
BwHNqWhratV6af2Upjq2YQ0fdSB42f3pgopInxNJPMv1Ab+cCfr0Pfwu7ge7UooQ
WHTxbpCvwtv/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/Zwa4by292ZeqRC9Ir2wdrizb69JbRjeshBw1JDAS/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/BMBBAGApBQJiTy4FAhsvBQkHhM4ABwsJCACDAgEGFQgCCQoLBBYCAwECHgEC
F4AACGkQAVWEKB9Eo8NpbxAAiBF0kR/1Vw3vuam60mk4l0iGMVsP8Xq6g/buzbE0
2MEB4Ftk04q0noa+93S0ZiLR9PqxrsGS4ADDX3Vtc4uxwzU1KU11ywEhQ1cwyl
YHQI3Hd75K1J81ozMEu6qJH+yF0TtTDZMeZHTH/XvuIYJW3Lx4o5ZF1sEegFPAGX
YCCpUS+k9qC6M8g2VjcltQJpyjGswsKm6FWaKHW+B9dfjd0H1ImB9E2jaknJ8eoY
zb9zHgFANluMzpZ6rYVSiCuXiEgYmazQWcVlPcMOP7nX+1hq1z11LMqeSnfE09gX
H+0Yho9cMEJkb1dzx1H9MRpylFIIn9tL+2iCp4UPJjnqi6uawWyL22tp4G11haqQq
1yAh69u233I8GZKFUySzjHwH5qWGRGBTjrZ6FdcjSS2w/wMkVKuCPkwtDvo/TJrm
msCd1Reye8SEKYqrs0ujTwm1vWmUZm006AdUjo1kWiBKes1TJrWEuG7Yk4pF0oA4
dsaq83gxp0JNVCh6M3y4DLNrv17dhF95NwTWMROPj2otw7NIjF4/cdzve2+P7YNN
pVAtyCtTjD3eZbQPvAl3T8cf1VGqt6++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+FhYrovU1gotb5D
YiCQI3ofV5QTE+141jh05PkD3ZIoBG+P826LaT8NXhwS0o1XqVkJ39DCZNoFshNmR
WFZpkVCTHyv5ZhVey1NWxND8op0375htGNV4AeSmSIH9YkURD1g5F+2t7RiosKfo
kJrfPmUjhHn8IFpReGc8qmMMZX0WaV3t+VAWfOHGGyrXDfQ4xz1VCot75C2+qypM
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-----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-----

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-----END PGP PUBLIC KEY BLOCK-----
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## 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-----

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=2Tag
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-----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="#">Document <code>cdk.json</code> (p. 354)</a>	Add documentation of <code>cdk.json</code> configuration values.	April 20, 2022
<a href="#">Dependency management (p. 354)</a>	Add topic on managing dependencies with the AWS CDK.	April 7, 2022
<a href="#">Remove double-braces from Java examples (p. 354)</a>	Replace this anti-pattern with Java 9 <code>Map.of</code> throughout.	March 9, 2022
<a href="#">AWS CDK v2 release (p. 354)</a>	Improvements to CDK v1 Developer Guide to coincide with the release of CDK v2 and its documentation.	December 4, 2021
<a href="#"><code>cdk watch</code> (p. 354)</a>	Add description of <code>cdk watch</code> command for incremental deployments.	November 19, 2021
<a href="#">Testing with assertions (p. 354)</a>	Revise testing topic to use new assertions library.	November 17, 2021
<a href="#">Experimental modules (p. 354)</a>	Explain how experimental modules work with CDK v2.	October 28, 2021
<a href="#">Faster local development (p. 354)</a>	Add information on <code>--no-rollback</code> and <code>--hotswap</code> options for accelerated local development.	October 7, 2021
<a href="#">Add local tooling information (p. 354)</a>	Update TypeScript and JavaScript topics with information on using locally-installed tools ( <code>cdk</code> , <code>tsc</code> ).	September 28, 2021
<a href="#">Update CDK Pipelines API (p. 354)</a>	Update CDK Pipelines topic to use new API.	August 24, 2021
<a href="#">CloudFormation Public Registry (p. 354)</a>	Add topic about using resource definitions from the CloudFormation Public Registry with the AWS CDK.	June 24, 2021
<a href="#">Best Practices topic (p. 354)</a>	Add topic about best practices for developing CDK apps.	June 10, 2021

<a href="#">Go developer preview (p. 354)</a>	Add information about Go language support (in developer preview) including a "Working with the CDK in Go" topic.	April 19, 2021
<a href="#">Import or migrate AWS CloudFormation template (p. 354)</a>	Add description of the new <code>cloudformation-include.CfnInclude</code> class, a powerful way to import and migrate AWS CloudFormation templates, or to vend them as AWS CDK constructs.	October 15, 2020
<a href="#">Add construct tree section (p. 354)</a>	Information about the construct tree and its relation to the constructs you define in your AWS CDK app.	October 5, 2020
<a href="#">Add Bootstrapping topic (p. 354)</a>	A complete explanation of why and how to bootstrap AWS environments for the CDK, including a comprehensive discussion of how to customize the process.	September 8, 2020
<a href="#">Add CDK Pipelines how-to (p. 354)</a>	CDK Pipelines let you easily automate the deployment of your AWS CDK apps from source control whenever they're updated.	July 17, 2020
<a href="#">Improve CDK Toolkit topic (p. 354)</a>	Include more information and examples around performing common tasks with the CLI (and the relevant flags) rather than just including a copy of the help.	July 9, 2020
<a href="#">Improve CodePipeline example (p. 354)</a>	Update pipeline stack to build in proper language and add more material dealing with the CodeCommit repository.	July 6, 2020
<a href="#">Improve Getting Started (p. 354)</a>	Remove extraneous material from Getting Started, use a more conversational tone, incorporate current best practices. Break out Hello World into its own topic.	June 17, 2020
<a href="#">Update stability index (p. 354)</a>	Incorporate the latest definitions of the stability levels for AWS Construct Library modules.	June 11, 2020
<a href="#">CDK Toolkit versioning (p. 354)</a>	Add information about cloud assembly versioning and compatibility of the CDK Toolkit (CLI) with the AWS Construct Library	April 22, 2020

<a href="#">Translating from TypeScript (p. 354)</a>	Updated "CDK in Other Languages" topic to also include JavaScript, Java, and C# and renamed it "Translating from TypeScript."	April 10, 2020
<a href="#">Parameters topic (p. 354)</a>	Add Concepts topic on using parameters with the AWS CDK.	April 8, 2020
<a href="#">JavaScript code snippets (p. 354)</a>	Reinstate JavaScript code snippets throughout (automated translation via Babel).	April 3, 2020
<a href="#">Working with the CDK (p. 354)</a>	Add "Working with the CDK" articles for the five supported languages. Various other improvements and fixes.	February 4, 2020
<a href="#">Java code snippets (p. 354)</a>	Add Java code snippets throughout. Designate Java and C# bindings stable.	November 25, 2019
<a href="#">C# code snippets (p. 354)</a>	Add C# code snippets throughout.	November 19, 2019
<a href="#">Python code snippets (p. 354)</a>	Add Python code snippets throughout. Add Troubleshooting and Testing topics.	November 14, 2019
<a href="#">Troubleshooting topic (p. 354)</a>	Add Troubleshooting topic to AWS CDK Developer Guide.	October 30, 2019
<a href="#">Improve Environments topic (p. 354)</a>	Add Troubleshooting topic to AWS CDK Developer Guide.	October 10, 2019
<a href="#">ECS Patterns improvements (p. 354)</a>	Updates to reflect improvements to ECS Patterns module.	September 17, 2019
<a href="#">New tagging API (p. 354)</a>	Update tagging topic to use new API.	August 13, 2019
<a href="#">General availability (p. 354)</a>	The AWS CDK Developer Guide is released.	July 11, 2019