

Getting Started with the Cloud

Software Architecture

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Brae Webb & Richard Thomas & Evan Hughes



Aside

Github Classroom links for this practical can be found on Edstem <https://edstem.org/au/courses/21491/discussion/2429006>

Before Class

Install Terraform¹ before your practical class. Also install the Terraform plugin for your IDE.

¹<https://learn.hashicorp.com/tutorials/terraform/install-cli>

1 This Week

This week our goal is to get acquainted with AWS Academy. We use AWS Academy to learn how to deploy and manage infrastructure with AWS. Additionally, AWS Academy will be used to develop the Cloud Infrastructure assignment. If you have not already enrolled in the AWS Academy courses, you need to do so now.

- AWS Academy **Practicals** Learner Lab [[110995](#)]
- AWS Academy **Assignment** Learner Lab [[112082](#)]
- AWS Academy Cloud Foundations [[110989](#)]
- AWS Academy Cloud Architecting [[110993](#)]
- AWS Academy Cloud Developing [[110994](#)]

This week you will learn how to:

- Navigate the AWS Academy interface, if you have not done so already.
- Enter the AWS Console from an AWS Academy lab.
- Provision an EC2 instance that deploys a simple static website.

We will then start using an Infrastructure as Code tool, specifically, Terraform, to deploy the static website instead of using the AWS Console. This week you will also learn how to:

- Authenticate Terraform to use the AWS Learner Lab.
- Configure a single server website in Terraform and deploy.
- Create a Terraform module for deploying arbitrary single server websites.

2 AWS Academy

AWS Academy is an educational platform to teach you how to use AWS services. In this course, we will be using it in two ways:

1. The AWS Cloud Foundations, Cloud Architecting, and Cloud Developing courses are supplementary material to help cement your ability to use AWS. You are encouraged to work your way through at least the AWS Cloud Foundations and Cloud Architecting courses.
2. The AWS Learner Lab ([110995](#)) provides access to an environment which will be used in these practicals to learn AWS. A separate Learn Lab ([112082](#)) will be used to develop your Cloud Infrastructure assignment. Remember that you have a \$50 USD budget for each Learner Lab. Once you have spent your budget, you will not be able to use the Learner Lab.

3 Enrol in AWS Academy

- Set up your AWS Academy account by responding to your email invitation and clicking **Get Started**. The email invitation will come from AWS Academy. Check your junk/spam folders.

Course Invitation ➤ Inbox x ▼ 🖨️

AWS Academy <notifications@instructure.com> 13:33 (14 minutes ago) ☆ 😊 ↳
to me ▾

You've been invited to participate in a class at AWS Academy . The class is called AWS Academy Learner Lab [73527]. Course role: Student

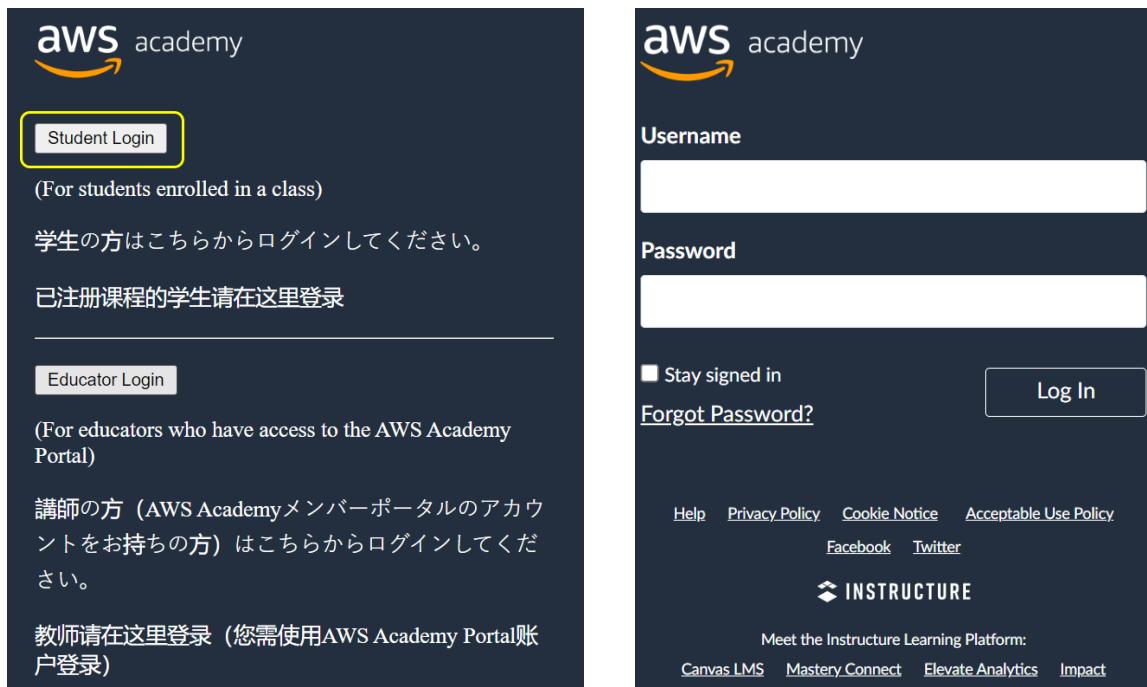
Name: [REDACTED]
Email: [REDACTED]
Username: **none**

You'll need to register with Canvas before you can participate in the class.

Get Started

- Go to https://www.awsacademy.com/vforcesite/LMS_Login to login.

- Press **Student Login**.
- Use the email address that received the email invitation.



4 Exploring the Interface

Aside

We will just be looking at the Learner Lab today, please ask on the Ed Discussion board if you need help using the supplementary AWS Academy courses.

Enter the Learner Lab via the following steps.

1. Once you have enrolled in the course, you should see the course page.

AWS Academy Learner Lab [110995]

AWS Academy Learner Lab provides a long-running sandbox environment for ad hoc exploration of AWS services. Within this class, students will have access to a restricted set of AWS services. Not all AWS documentation walk-through or sample labs that operate in an AWS Production account will work in the Learner Lab environment. You will retain access to the AWS resources set up in this environment for the duration of this course. We limit your budget (\$50USD), so you should exercise caution to

2. Navigate to the Modules tab and select the link for “Launch AWS Academy Learner Lab”. You will need to accept the AWS Learner Lab terms and conditions to be able to launch learner lab. You may also open and browse the “AWS Academy Learner Lab Student Guide” and “Learn how to effectively use the AWS Academy Learner Lab” links, which cover some of the content of this practical.

Course Welcome and Overview

Pre-Course Survey

AWS Academy Learner Lab Student Guide

AWS Academy Learner Lab Compliance and Security

Learn how to effectively use the AWS Academy Learner Lab

Module Knowledge Check
100 pts Score at least 70.0

AWS Academy Learner Lab

Launch AWS Academy Learner Lab

AWS Academy Learner Lab Resources

Demo - How to Access Learner Lab

Demo - General Troubleshooting Tips

Demo - How to Launch Services through AWS Console

Learner Lab Activity - Amazon Q Developer

Complete All Items

3. You should now see the Learner Lab interface.

- The AWS text, near the top left of the window, with the (currently) red circle is the link to open the AWS console.
 - You can also see your budget. Note that the budget is not updated in real-time, so avoid creating multiple resources at once.
 - The 00:00 is a countdown of hours remaining for your lab. A lab can only remain active for 4 hours, after which it will close, unless you press start lab again before the 4 hours expires. Once the lab is started, 00:00 will change to 04:00.
 - AWS details will become important later but are not needed now.
 - The README button will re-open the text panel currently on the right of the terminal interface.
 - The README text has a lot of important information including what AWS services are available in the learner labs environment, please read it.
 - The terminal interface is an environment with the SSH keys required to connect to AWS instances semi-automatically (we will use this today).

The screenshot shows the AWS Academy Learner Lab interface. The top navigation bar includes the AWS Academy logo, the path 'ALLv2EN-US-LTI1... > Modules > AWS Academy Le... > Launch AWS Academy Learner Lab', and action buttons for 'Start Lab', 'End Lab', 'AWS Details', 'Readme', and 'Reset'. On the left, a dark sidebar menu lists 'Home', 'Modules' (selected), 'Discussions', 'Grades', 'Lucid (Whiteboard)', 'Courses', 'Calendar', 'Inbox', 'History', and 'Help' (with a notification count of 3). The main content area features a terminal window with the command 'eee_w_4144423@runweb161444:~\$' and a dropdown menu set to 'EN-US'. To the right, a large section titled 'Learner Lab' contains a 'Environment Overview' table with links to various AWS services like the Management Console, CLI, SDK, and budget preservation. Below the table, a note states 'Instructions last updated: 2025-02-03'. A 'Environment Overview' section describes the sandbox environment for AWS service exploration. Another section explains that sessions are long-lived, retaining data and resources. A note at the bottom right indicates that EC2 instances are stopped and restarted, while SageMaker notebooks are stopped but not restarted.

Link	Description
Environment Overview	This Learner Lab provides a sandbox environment for ad-hoc exploration of AWS services.
Environment Navigation	
Access the AWS Management Console	
Region restriction	
Service usage and other restrictions	
Using the terminal in the browser	
Running AWS CLI commands	
Using the AWS SDK for Python	
Preserving your budget	
Accessing EC2 Instances	
SSH Access to EC2 Instances	
SSH Access from Windows	
SSH Access from a Mac	

Instructions last updated: 2025-02-03

Environment Overview

This Learner Lab provides a sandbox environment for ad-hoc exploration of AWS services.

This environment is long-lived. When the session timer runs to 0:00, the session will end, but any data and resources that you created in the AWS account will be retained. If you later launch a new session (for example, the next day), you will find that your work is still in the lab environment.

Running EC2 instances will be stopped and then automatically restarted the next time you start a session. SageMaker notebook instances will be stopped, but not restarted the next time you start a session. SageMaker canvas apps will remain running unless you delete them.

IMPORTANT: Monitor your lab budget in the lab interface above. Whenever you have an active lab session, the latest known remaining budget information will display.

Notice

If you get an error message saying “`labs.vocareum.com` refused to connect.”, ensure that your browser is not in the incognito mode. If you still encounter this error, try using a different browser.

4. Go ahead and start the lab. It will take a few moments to get ready. The red circle will turn yellow as the lab is starting, and green once it has started. Click on the AWS text with the green circle when it is available. This will open the AWS Console in a new browser tab. (You may need to enable pop-ups from awsacademy.) If you end up working for a company which uses AWS, welcome to your new home.

The screenshot shows the AWS Console Home page with the following sections:

- Recently visited:** Shows a placeholder icon and a message "No recently visited services". Buttons for EC2, S3, RDS, and Lambda are present.
- Applications:** Shows 0 applications. A "Create application" button is available.
- Welcome to AWS:**
 - Getting started with AWS:** Learn fundamentals and find valuable information.
 - Training and certification:** Learn from AWS experts and advance your skills.
 - What's new with AWS:** Discover new AWS services, features, and Regions.
- AWS Health:** Shows 0 open issues, 0 scheduled changes, and 0 other notifications. A "Go to AWS Health" button is available.
- Cost and usage:** Shows current month costs at \$0.00 and forecasted month end costs at \$0.01. A bar chart tracks spending by service over time. A "Go to Billing and Cost Management" button is available.
- Solutions (18):** Vetted Solutions from AWS for popular business and technical use cases. Options include Generative AI Application Builder and Live Streaming. A navigation bar shows pages 1, 2, 3, and 4.
- Explore AWS:** Explore training for coding experts seeking to integrate the latest AI... A "Learn AI" button is available.
- Security:** Region: US East (N. Virginia). A "Deploy LLMs with confidence" button is available.

Aside

Amazon Web Services (AWS) is an Infrastructure as a Service (IaaS) and Software as a Service (SaaS) provider. They offer a collection of services which are helpful for development. For example, they offer virtual compute resources, database storage options, and networking to tie it all together. Services are offered on a pay as you go model, meaning you only pay for the seconds you use a service. We will now get acquainted with some simple services offered by AWS.

5 AWS EC2

Today we are focussing on using AWS's EC2 service. Elastic Compute Cloud (EC2) is the primary compute service offered by AWS. It allows you to create virtual machines on Amazon's infrastructure. You have full control over this machine and can configure it for whatever purpose you need.

Navigate to the search bar in the top left and find the EC2 service. You might find this interface overwhelming. It is important to note that since EC2 is one of the primary services offered by AWS, many smaller services we do not need are bundled into this service.

The screenshot shows the AWS Console Services page. On the left, there is a sidebar with 'Console' and 'Recent' sections. Under 'Services', there are links to Features, Resources (marked as 'New'), Documentation, Knowledge articles, Marketplace, Blog posts, Events, and Tutorials. The main content area displays the 'EC2' service card, which includes a thumbnail icon, the service name, a brief description ('Virtual Servers in the Cloud'), and a 'Top features' section with links to Dashboard, Launch templates, Instances, Spot Instance requests, and Savings plans. Below this are cards for 'EC2 Image Builder', 'EC2 Global View', and 'Recycle Bin'. A 'Features' section is shown with a 'Show more' link, and a 'Dashboard' link is at the bottom.

Today, we only need the Instances dashboard. Navigate to there and select “Launch instance”.

The screenshot shows the AWS Instances dashboard. The left sidebar includes sections for Dashboard, Resources, Instances, Images, Elastic Block Store, Network & Security, and Load Balancing. The main content area has a 'Resources' summary card with counts for Instances (running), Auto Scaling Groups, Capacity Reservations, Dedicated Hosts, Elastic IPs, Instances, Key pairs, Load balancers, Placement groups, Security groups, Snapshots, and Volumes. Below this are cards for 'Launch instance' (with 'Launch instance' and 'Migrate a server' buttons), 'Service health' (with 'AWS Health Dashboard' and status 'This service is operating normally'), 'Zones' (listing regions like us-east-1a through us-east-1f with their respective Zone IDs), 'Instance alarms' (showing 0 in alarm, 0 OK, and 0 insufficient data), 'Scheduled events' (with a 'C' icon), and 'Explore AWS' (sections for Best Price Performance, Graviton2, GuardDuty Malware Protection, and Additional information). A 'Get started guide' link is also present.

5.1 EC2 AMI

First we will need to select an Amazon Machine Image (AMI). An AMI is the template that provides instructions on how an instance should be provisioned. Amazon offers a range of built-in AMIs. There are also community AMIs or you can create your own. As we just want a simple server today, we will use one of the built-in AMIs.

We will use the Amazon Linux 2023 AMI today, it is considered one of the fundamental images. Every AMI has a unique AMI code, which is `ami-08b5b3a93ed654d19` for the Amazon Linux 2023 AMI.

The screenshot shows the AWS EC2 'Launch an instance' interface. In the 'Name and tags' section, the name 'e.g. My Web Server' is entered. Under 'Application and OS Images (Amazon Machine Image)', the 'Amazon Linux 2023 AMI' is selected, with its AMI ID `ami-053a45ffff0a704a47` visible. The 'Instance type' section shows 't2.micro' selected. On the right, a summary box details the free tier benefits: 750 hours of t2.micro (or t3.micro) usage per month, 750 hours of public IPv4 address usage per month, 30 GB of EBS storage, 2 million I/Os, 1 GB of snapshots, and 100 GB of bandwidth to the internet. A large orange 'Launch instance' button is prominent at the bottom right.

5.2 Instance Settings

The settings to configure your instance are:

1. Add a 'Name' tag. Call it the name of your website, e.g. `hextris`.
2. Select an appropriate AMI, i.e. Amazon Linux 2023 AMI, `ami-053a45ffff0a704a47`.
3. Select a 64-bit (x86) architecture.
4. The instance type defines the computing, memory, networking and storage capabilities of your instance. We do not need a large server, choose `t2.micro`.

5. Select the existing vockey (Type: RSA) key pair option.
6. In network settings, choose ‘Create security group’ and select to allow SSH traffic from anywhere, and HTTPS and HTTP access from the internet.
7. Keep the ‘Configure storage’ settings as default.
8. Do not worry about the ‘Advanced details’ options for now.
9. You can now launch the instance to start your server.

6 Accessing the Instance

Return to the Instances dashboard. You should see that a new instance has been created. Its instance state might not yet be Running, if not, wait.

The screenshot shows the AWS EC2 Instances dashboard. On the left, there's a sidebar with various navigation links: Dashboard, EC2 Global View, Events, Instances (selected), Instances Types, Launch Templates, Spot Requests, Savings Plans, Reserved Instances, Dedicated Hosts, Capacity Reservations, Images, AMIs, AMI Catalog, Elastic Block Store, Volumes, Snapshots, Lifecycle Manager, Network & Security, Security Groups, Elastic IPs, Placement Groups, Key Pairs, Network Interfaces, Load Balancing, Load Balancers, Target Groups, Trust Stores, Auto Scaling, Auto Scaling Groups, and Settings.

The main content area displays the 'Instances (1/1)' section. It shows one instance named 'hextris' with the following details:

- Instance ID:** i-0e4a4edee40a78ee5
- Instance state:** Running
- Instance type:** t2.micro
- Status check:** Initializing
- View alarms:** +
- Availability Zone:** us-east-1c
- Public IPv4 DNS:** ec2-3-90-102-7

Below this, the specific instance details for 'i-0e4a4edee40a78ee5 (hextris)' are shown in a tabular format:

Details			Status and alarms	Monitoring	Security	Networking	Storage	Tags
Instance summary <small>Info</small>								
Instance ID	i-0e4a4edee40a78ee5	Public IPv4 address	3.90.102.76	open address	Running	Private IPv4 addresses	172.31.17.121	
IPv6 address	-	Instance state	ip-172-31-17-121.ec2.internal		Private IP DNS name (IPv4 only)	ip-172-31-17-121.ec2.internal	Public IPv4 DNS	ec2-3-90-102-76.compute-1.amazonaws.com
Hostname type	IP name: ip-172-31-17-121.ec2.internal	Private IP DNS name (IPv4 only)	ip-172-31-17-121.ec2.internal		Instance type	t2.micro	Elastic IP addresses	-
Answer private resource DNS name	IPv4 (A)	Instance type	t2.micro		VPC ID	vpc-061883ee56a945fb1	AWS Compute Optimizer finding	Opt-in to AWS Compute Optimizer for recommendations.
Auto-assigned IP address	3.90.102.76 [Public IP]	VPC ID	vpc-061883ee56a945fb1		Subnet ID	subnet-039f54cf211a5e662	Auto Scaling Group name	-
IAM Role	-	Subnet ID	subnet-039f54cf211a5e662		Instance ARN	arn:aws:ec2:us-east-1:037666547461:instance/i-0e4a4edee40a78ee5	Managed	false
IMDSv2	Required	Instance ARN	arn:aws:ec2:us-east-1:037666547461:instance/i-0e4a4edee40a78ee5		Platform details	Linux/UNIX	Termination protection	
Operator	-	Platform details	Linux/UNIX		Termination protection			
Instance details <small>Info</small>								
AMI ID	ami-053a45fff0a704a47	Monitoring	disabled					
AMI name		Allowed image						

Note the public IPv4 address, as we will need to use this to connect to the server. You will also need this address to test that installation of Hextris in section 7 worked.

1. Return to the AWS Learner Lab interface.
2. Run the following, replacing `127.0.0.1` with the public IP address of your instance. This command uses the vockey | RSA key pair to gain SSH access to the machine.

```
$ ssh -i ~/.ssh/labsuser.pem ec2-user@127.0.0.1
```

For example:

```
eee_W_2897588@runweb113237:~$ ssh -i ~/.ssh/labsuser.pem ec2-user@3.95.132.33
The authenticity of host '3.95.132.33 (3.95.132.33)' can't be established.
ECDSA key fingerprint is SHA256:BArUeylQormBYN/FANocVRnn+HM9n8X+cn0BRn7hNiE.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '3.95.132.33' (ECDSA) to the list of known hosts.

,      #
~\_ ####_      Amazon Linux 2023
~~ \####\_
~~  \###|
~~    \#/ __ https://aws.amazon.com/linux/amazon-linux-2023
~~     \~' '-'>
~~      /
~~.._  /
~/_/
/_m/'[ec2-user@ip-172-31-80-172 ~]$ []
```

You can also access the instance by selecting it from the list of instances in the dashboard and clicking the "Connect" button. This will open a new tab in your browser with terminal access to your instance.

7 Installing Hextris

Hextris [1] is very simple to install. Using an EC2 interface is perhaps overkill for it. It is an entirely client-side/static web application, which means we just have to serve the static files.

First, we will need to enable serving of static files. We can install and start the `httpd` service to do this. The AMI we have picked uses the `yum` package manager, so to install `httpd` we run:

```
> sudo yum install httpd
Last metadata expiration check: ...
Dependencies resolved
.....
Total download size: 2.3 M
Installed size: 6.9 M
Is this ok [y/N] :

# enter y to install
.....
Complete!
> sudo systemctl enable httpd
Created symlink from /etc/systemd/system/multi-user.target.wants/httpd.service to /
    usr/lib/systemd/system/httpd.service.
> sudo systemctl start httpd
```

All files in the `/var/www/html` directory will now be served when accessed via **HTTP**. Navigate to the public IP address of your EC2 instance in the browser. You should see an "It works!" landing page.

Change to the `/var/www/html` directory and notice that it is currently empty. We need to download the static files to this directory so that they can be served. We can use git for this (though it is not the most suited tool), but first git needs to be installed on the instance.

```
$ sudo yum install git
```

Finally, confirm that we are in the `/var/www/html` directory.

```
$ cd /var/www/html
```

And clone the repository into that directory.

```
$ sudo git clone https://github.com/Hextris/hextris .
```

Now if you navigate to the **http** address of the public IP address (e.g. <http://18.208.165.253>), you should be able to see your newly deployed website. Congratulations!

Notice

If you are having timeout issues, one problem could be using `https` to connect rather than `http`.

8 Switching to Terraform

For the remainder of the practical we will use Terraform to provision the same instance we just created.

1. First, please delete any running instances in your AWS account using the AWS Console.
2. Next, navigate to the GitHub Classroom link for this practical provided at the start of this document. This will create a new repository where we can work on Terraform.

9 Using Terraform in AWS Learner Labs

We will redeploy our Hextris application using Infrastructure as Code (IaC) to do so. You will need to keep your lab running for the next steps. (Now is a good time to click start to refresh your 4 hours.)

1. Click on 'AWS Details' to display information about the lab.

The screenshot shows the AWS Academy Learner Lab interface. On the left is a sidebar with icons for Account, Dashboard, Courses, Calendar, Inbox, History, and Help. The main area has tabs for Home, Modules, Discussions, and Grades. A central window shows a terminal session with the command [ec2-user@ip-172-31-88-93 html]\$. To the right is a 'Cloud Access' panel. It shows 'AWS CLI' with a 'Show' button, 'Cloud Labs' with session details (Remaining session time: 01:55:16(116 minutes), Session started at: 2024-02-15T20:09:23-0800, Session to end at: 2024-02-16T00:09:23-0800), and 'Accumulated lab time: 02:04:00 (124 minutes)'. It also lists 'No running instance'. Below that are buttons for 'SSH key Show', 'Download PEM', 'Download PK', 'AWS SSO Download URL', and a table with 'AWSAccountid' (058264123001) and 'Region' (us-east-1).

2. Click on the first 'Show' button next to 'AWS CLI' which will display a text block starting with [default].
3. Within your repository create a credentials file and copy the contents of the text block into the file. **Do not share this file contents — do not commit it.** This file is added to the .gitignore of your repository by default.
4. Create a `main.tf` file in the same directory with the following contents:

```
> cat main.tf

terraform {
    required_providers {
        aws = {
            source = "hashicorp/aws"
            version = "~> 5.0"
        }
    }
}

provider "aws" {
    region = "us-east-1"
    shared_credentials_files = ["./credentials"]
    default_tags {
        tags = {
            Environment = "Dev"
            Course = "CSSE6400"
            StudentID = "<Your Student ID>"
        }
    }
}
```

The `terraform` block specifies the required external dependencies, here we need to use the AWS provider above version 5.0. The `provider` block configures the AWS provider, instructing it which region to use and how to authenticate (using the credentials file we created). We also include some tags to add to any resource made by this provider, these are useful for keeping track of resources in the console.

5. We need to initialise Terraform, which will download the required dependencies. This is done with the `terraform init` command.

```
$ terraform init
```

This command will create a `.terraform` directory which stores providers and a provider lock file, `.terraform.lock.hcl`.

6. To verify that we have setup Terraform correctly, use `terraform plan`.

```
$ terraform plan
```

As we currently have no resources configured, it should find that no changes are required. Note that this does not ensure our credentials are correctly configured, as Terraform has no reason to try authenticating yet.

10 Deploying Hextris

First, we will need to create an EC2 instance resource. The AWS provider calls this resource an [aws_instance](#)². Get familiar with the documentation page. Most Terraform providers have reasonable documentation. Reading the argument reference section helps to understand what a resource is capable of doing.

We will start off with the basic information for the resource. Configure it to use a specific Amazon Machine Instance (AMI), and chose the `t2.micro` size. We will also give it a name so that it is easy to find. Add the following basic resource block to `main.tf`:

```
> cat main.tf
resource "aws_instance" "hextris-server" {
  ami = "ami-08b5b3a93ed654d19"
  instance_type = "t2.micro"
  key_name = "vockey"

  tags = {
    Name = "hextris"
  }
}
```

To create the server, invoke `terraform apply`, which will first do `terraform plan` and prompt us to confirm if we want to apply the changes.

```
$ terraform apply
```

You should be prompted with something similar to the output below.

²<https://registry.terraform.io/providers/hashicorp/aws/latest/docs/resources/instance>

```
Terraform used the selected providers to generate the following execution plan.
```

```
Resource actions are indicated with the following symbols:
```

```
+ create
```

```
Terraform will perform the following actions:
```

```
# aws_instance.hextris-server will be created
+ resource "aws_instance" "hextris-server" {
    + ami = "ami-08b5b3a93ed654d19"
    (omitted)
    + instance_type = "t2.micro"
    (omitted)
    + tags = {
        + "Name" = "hextris"
    }
    (omitted)
}
```

```
Plan: 1 to add, 0 to change, 0 to destroy.
```

```
Do you want to perform these actions?
```

```
Terraform will perform the actions described above.
```

```
Only 'yes' will be accepted to approve.
```

```
Enter a value:
```

If the plan looks sensible enter yes to enact the changes.

```
Enter a value: yes
```

```
aws_instance.hextris-server: Creating...
aws_instance.hextris-server: Still creating... [10s elapsed]
aws_instance.hextris-server: Still creating... [20s elapsed]
aws_instance.hextris-server: Still creating... [30s elapsed]
aws_instance.hextris-server: Still creating... [40s elapsed]
aws_instance.hextris-server: Creation complete after 47s [id=i-08c92a097ae7c5b18]
```

```
Apply complete! Resources: 1 added, 0 changed, 0 destroyed.
```

You can now check in the AWS Console that another EC2 instance with the name `hextris` has been created. Now that we have a server, we should try to configure it to serve Hextris. We will use the `user_data` field, which configures commands to run when launching the instance. First we need a script to provision the server, if we combine all our commands from section 7, we will produce this script:

```
» cat serve-hextris.sh
#!/bin/bash
yum install -y httpd
```

```
systemctl enable httpd
systemctl start httpd

yum install -y git
cd /var/www/html
git clone https://github.com/Hextris/hextris .
```

Now we can add the following field to our Terraform resource. It uses the Terraform `file` function to load the contents of a file named `serve-hextris.sh`, relative to the Terraform directory. The contents of that file is passed to the `user_data` field.

```
user_data = file("./serve-hextris.sh")
```

If you run the `terraform plan` command now, you will notice that Terraform has identified that this change will require creating a new EC2 instance. Where possible, Terraform will try to update a resource in-place but since this changes how an instance is started, it needs to be replaced. Go ahead and apply the changes.

Now, in theory, we should have deployed Hextris to an EC2 instance. But how do we access that instance? We *could* go to the AWS Console and find the public IP address. However, it turns out that Terraform already knows the public IP address. In fact, if you open the Terraform state file (`terraform.tfstate`), you should be able to find it hidden away in there. But, we do not want to go hunting through this file all the time. Instead we will use the `output` keyword.

We can specify certain attributes as 'output' attributes. Output attributes are printed to the terminal when the module is invoked directly but as we will see later, they can also be used by other Terraform configuration files.

```
output "hextris-url" {
  value = aws_instance.hextris-server.public_ip
}
```

This creates a new output attribute, `hextris-url`, which references the `public_ip` attribute of our `hextris-server` resource. Note that resources in Terraform are addressed by the resource type (`aws_instance`) followed by the name of the resource (`hextris-server`).

If you apply the changes, it should tell you the public IP address of the instance resource.

```
$ terraform apply
```

```
aws_instance.hextris-server: Refreshing state... [id=i-043a61ff86aa272e0]
```

Outputs:

```
hextris-url = "3.82.225.65"
```

You can apply this plan to save these new output values to the Terraform state, without changing any real infrastructure.

So let's try and access that URL, hmm. That is strange. Something has gone wrong.

11 Security Groups

When we setup our EC2 instance using the AWS Console, it helpfully created a new security group for us. We specified that this security group should allow SSH, HTTP, and HTTPS traffic by allowing traffic from ports 22, 80, and 443 respectively. When configuring with Terraform, security groups and their attachment to EC2 instances are separate resources. Refer back to the Terraform documentation for details or, as is normally quicker, [Google “terraform aws security group”](#).

First, let us create an appropriate security group. Recall that in the AWS Console configuration, ingress SSH access (port 22) and all egress³ traffic were automatically configured and we just added ingress port 80. In Terraform the whole state must be configured so we specify two `ingress` blocks, one for HTTP (port 80) and one for SSH access (port 22).⁴ Additionally, we will create egress for all outgoing traffic.

```
resource "aws_security_group" "hextris-server" {
  name = "hextris-server"
  description = "Hextris HTTP and SSH access"

  ingress {
    from_port = 80
    to_port = 80
    protocol = "tcp"
    cidr_blocks = ["0.0.0.0/0"]
  }

  ingress {
    from_port = 22
    to_port = 22
    protocol = "tcp"
    cidr_blocks = ["0.0.0.0/0"]
  }

  egress {
    from_port = 0
    to_port = 0
    protocol = "-1"
    cidr_blocks = ["0.0.0.0/0"]
  }
}
```

Note the following:

- `from_port` and `to_port` are the start and end of a range of ports rather than incoming or outgoing. In this example our range is 80-80.
- `protocol` set to “-1” is a special flag to indicate all protocols.
- Explaining `cidr` is outside the scope of the course, but the specified block above means to apply to all IP addresses.

³Ingress and egress in networking just means incoming and outgoing respectively.

⁴We do not actually need SSH access as all the server configuration is done when the machine is provisioned, thanks to the `user_data`, but we are trying to create a new instance that is identical to the original AWS Console in section 7.

You may now apply the changes to create this new security group resource.

Next, we will attach the security group to the EC2 instance. Return to the `aws_instance.hextrix-server` resource and include the following line:

```
security_groups = [aws_security_group.hextris-server.name]
```

Note that EC2 instances can have multiple security groups. Once again notice the structure of resource identifiers in AWS.

Now apply the changes. If you now try to access via the IP address (the IP address may have changed), you should be able to view the Hextris website.

12 Tearing Down

One of the important features of Infrastructure as Code (IaC) is all the configuration we just did is stored in a file. This file can, and should be, version controlled and subject to the same quality rules of code files. It also means that if we want to redeploy Hextris at any point, we can easily just run the IaC to deploy it.

To try this out, let us first take everything down. We can do this with:

```
$ terraform destroy
```

You should be prompted to confirm that you want to destroy all of the resources in the state. Once Terraform has finished taking everything down, confirm that you can no longer access the website and that the AWS console says the instances have been destroyed.

Now go ahead and apply the changes to bring everything back:

```
$ terraform apply
```

Confirm that this brings the website back exactly as before (with a different IP address). You can now start any lab you want and almost instantly spin back up the website you have configured. That is the beauty of Infrastructure as Code!

Hint: Destroy everything again before you finish.

13 Automated Testing

A quick note about automated testing. As with all the practicals thus far, this practical has automated tests enabled on your repository.

From within your repository, you can run the tests locally with:

```
$ .csse6400/bin/unittest.sh
```

While the emails saying that the tests failed can be annoying, these automated tests allow us to ensure that everyone is keeping up with the practical content.

If fixing the test failures is not too hard, please try to do so. If you are repeatedly not passing the practicals, we may reach out to ensure that you are not being left behind in the content.

14 Extension

Info

This section is for students who have completed the practical and want to extend their knowledge.

Since CSSE6400 runs this practical every year, sometimes the AMI that we were using is out of date or does not exist any more. For this practical, we could instead query AWS for the latest AMI and use that in our Terraform.

To do this we introduce a new data source, `aws_ami`. Data sources fetch or query data from the provider, rather than creating something.

Add the following to your `main.tf` file:

```
data "aws_ami" "latest" {
  most_recent = true
  owners = ["amazon"]

  filter {
    name = "name"
    values = ["al2023-ami-2023*"]
  }

  filter {
    name = "root-device-type"
    values = ["ebs"]
  }

  filter {
    name = "virtualization-type"
    values = ["hvm"]
  }

  filter {
    name = "architecture"
    values = ["x86_64"]
  }
}
```

The `aws_ami` data source will find the latest Amazon Linux 2023 AMI for 64 bit x86, which is what is running on our EC2 instance.

To use the data source we need to change the `ami` attribute of the `aws_instance` resource to use the data source. This is done as so:

```
resource "aws_instance" "hextris-server" {
  ami = data.aws_ami.latest.id
  instance_type = "t2.micro"
  key_name = "vokey"
  security_groups = [aws_security_group.hextris-server.name]
  user_data = file("./serve-hextris.sh")
```

```

tags = {
  Name = "hextris"
}
}

```

And now, if we run `terraform plan`, we will see that it wants to destroy and recreate the EC2 instance. This is because the AMI has changed since this practical was first updated for this year.

References

- [1] L. Engstrom, G. Finucane, N. Moroze, and M. Yang, “Hextris.” <https://github.com/hextris/hextris/>, 2014.
- [2] “Aws global infrastructure.” <https://aws.amazon.com/about-aws/global-infrastructure/>, March 2025.

A AWS Networking Terminology

AWS Regions Regions are the physical locations of AWS data centres. When applying Terraform, the changes are being made to one region at a time. In our case we specified the region `us-east-1`. Often you do not need to deploy to more than one region, however, it can help decrease latency and reduce risk from a major disaster. Generally, pick a region and stick with it, we have picked `us-east-1` because it is the least expensive.



Figure 1: AWS Regions as of March 2025 [2]

Availability Zones An AWS Region will consist of availability zones, normally named with letters. For example, the AWS Region located in Sydney, ap-southeast-2 has three availability zones: ap-southeast-2a, ap-southeast-2b, and ap-southeast-2c. An availability zone is a collection of resources which run on separate power supplies and networks. Reducing the risk that multiple availability zones would fail at once.

VPC Virtual Private Clouds, or VPCs, are virtual networks under your control, if you have managed a regular network before it should be familiar. VPCs are contained within one region but are spread across multiple availability zones.