Getting Started with the Cloud

Software Architecture

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Aside

Github Classroom links for this practical can be found on Edstem https://edstem.org/au/courses/33564/discussion/3127162

Before Class

Install Terraform[1] *before* your practical class. Also install the Terraform plugin for your IDE.

[1] https://developer.hashicorp.com/terraform/tutorials/aws-get-started/install-cli

1 This Week

Our goal is to get acquainted with AWS Academy Learner Lab. We use the lab to learn how to deploy and manage infrastructure with AWS. Additionally, Learner Lab 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.

- Introduction to AWS Academy notes[2] describes how to accept your invitation to enrol and login to AWS Academy.
- Introduction to AWS Academy: Learner Lab notes[3] describes how to access and use Learner Lab.

You will learn how to:

- Enter the AWS Console from a Learner Lab.
- Provision an EC2 instance that deploys a simple static website.

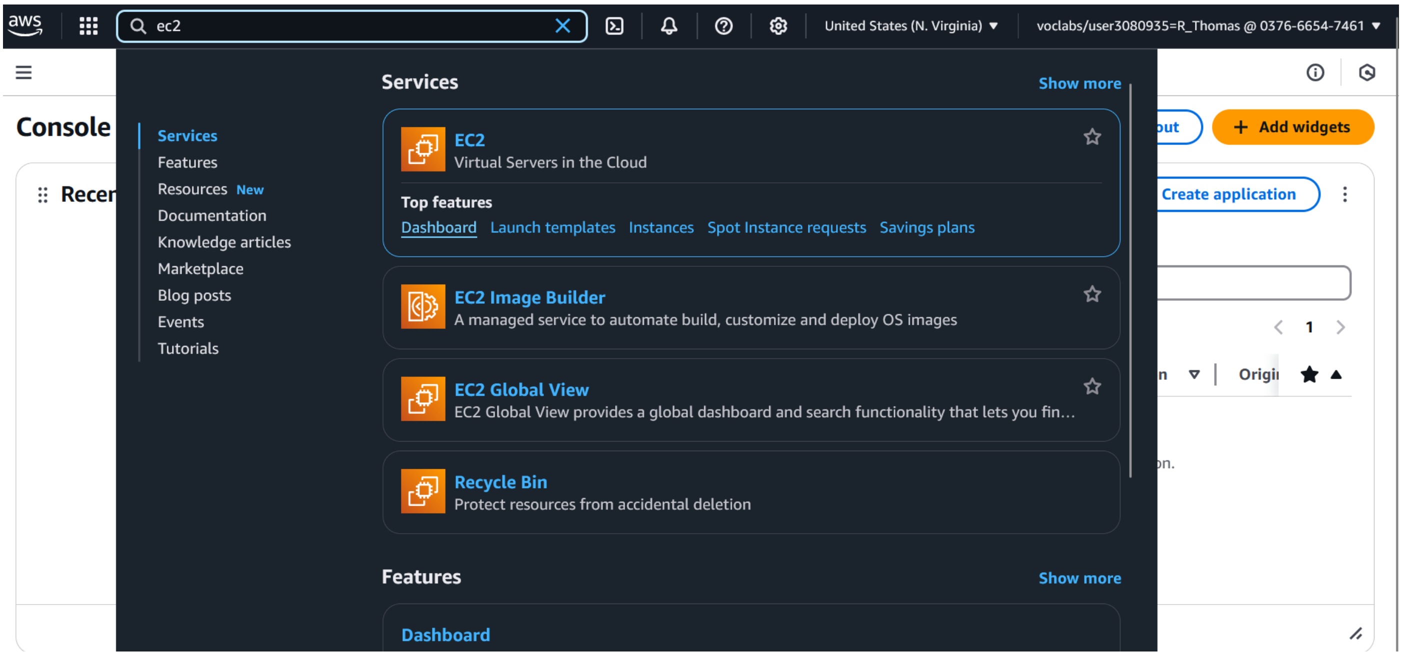
We will then start using an Infrastructure as Code tool (Terraform) to deploy the static website instead of using the AWS Console. You will also learn how to:

- 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 EC2

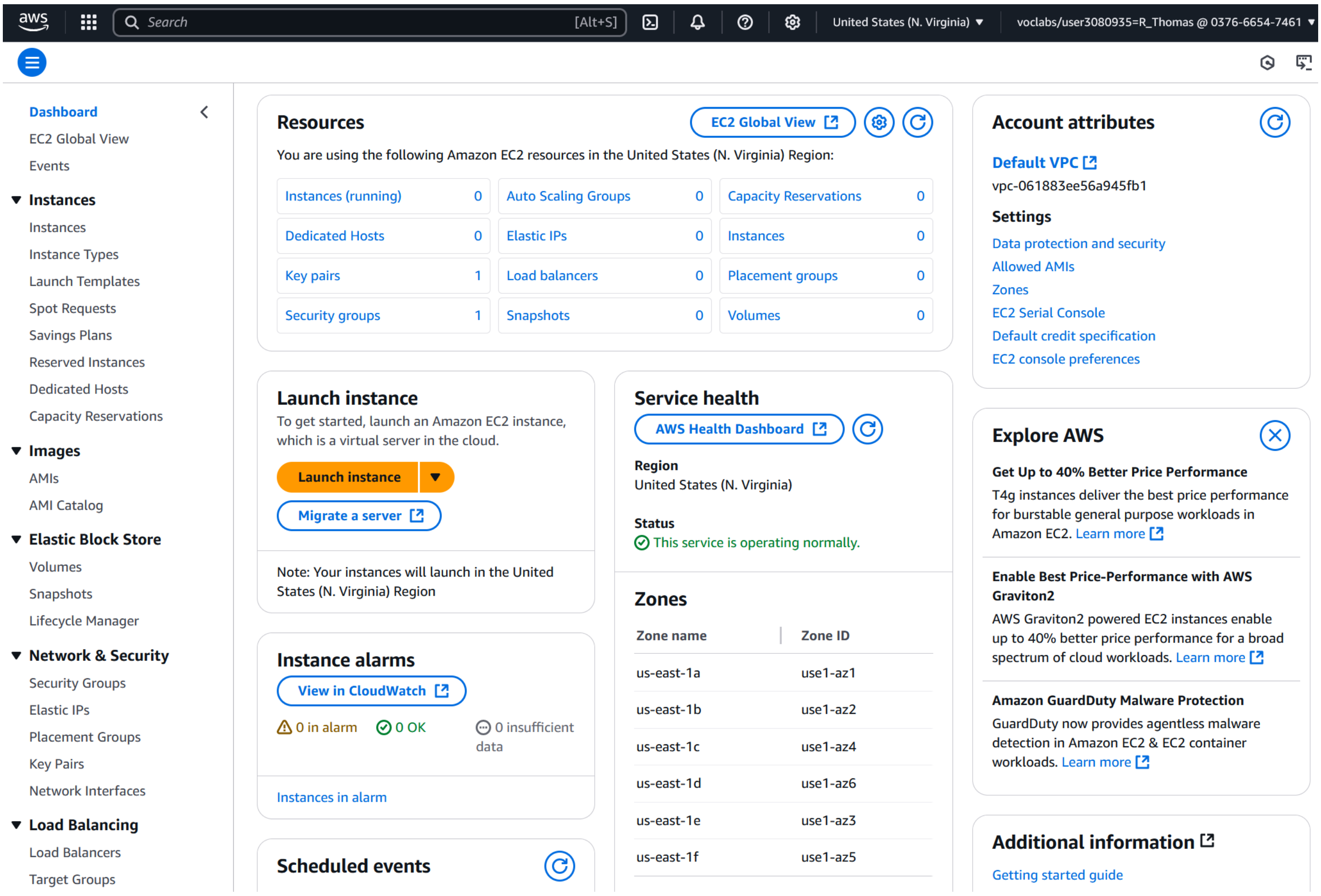
Today we are focussing on using AWS's EC2 service. Elastic Compute Cloud (EC2) is the primary compute service offered by AWS. It allows you to create virtual machines on Amazon's infrastructure. You have full control over this machine and can configure it for whatever purpose you need.

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.



[2] https://csse6400.uqcloud.net/handouts/aws-academy.pdf
[3] https://csse6400.uqcloud.net/handouts/learner-lab.pdf

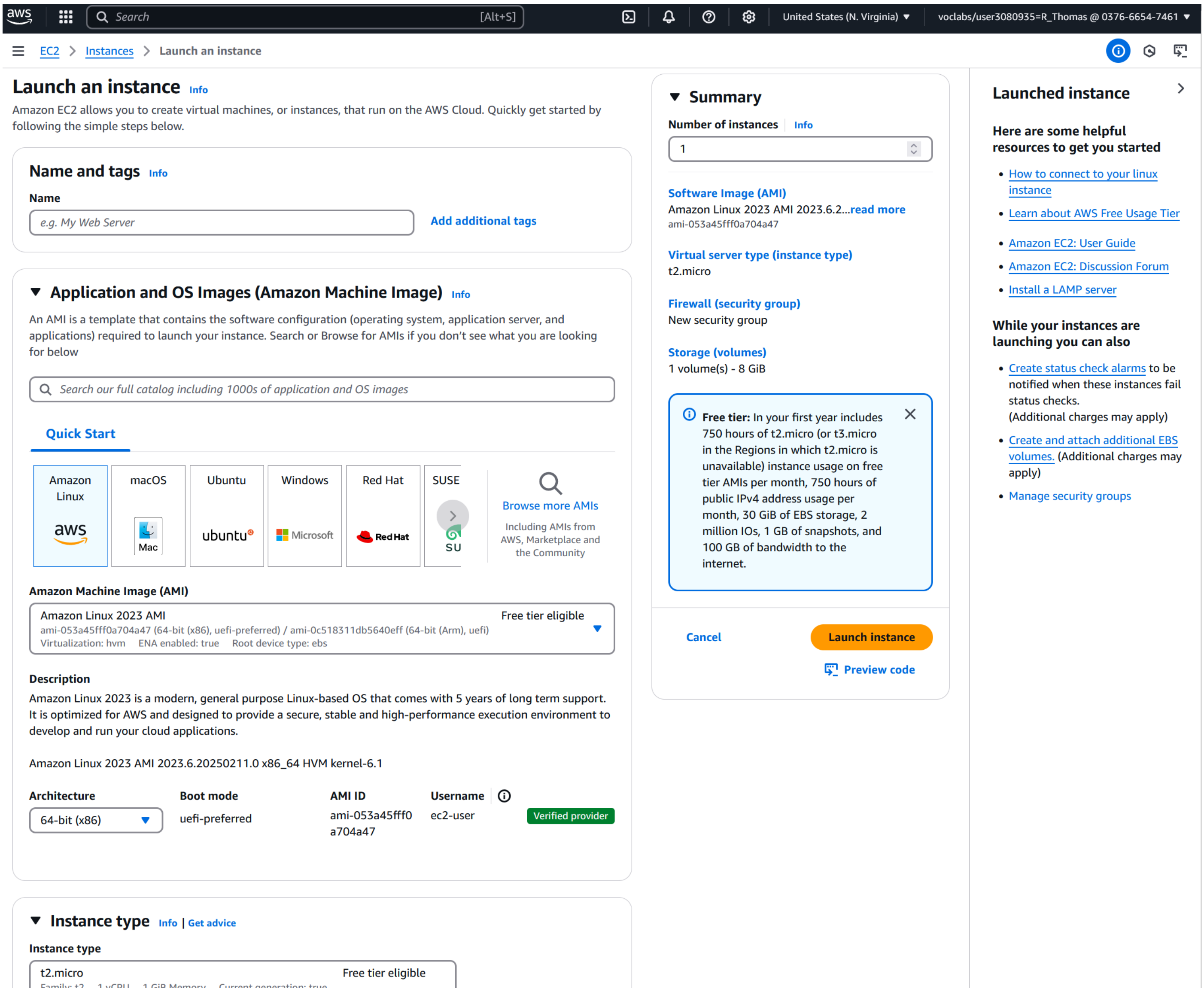
Today, we only need the `Instances` dashboard. Navigate to there and select “Launch instance”.



2.1 EC2 AMI

First we 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.



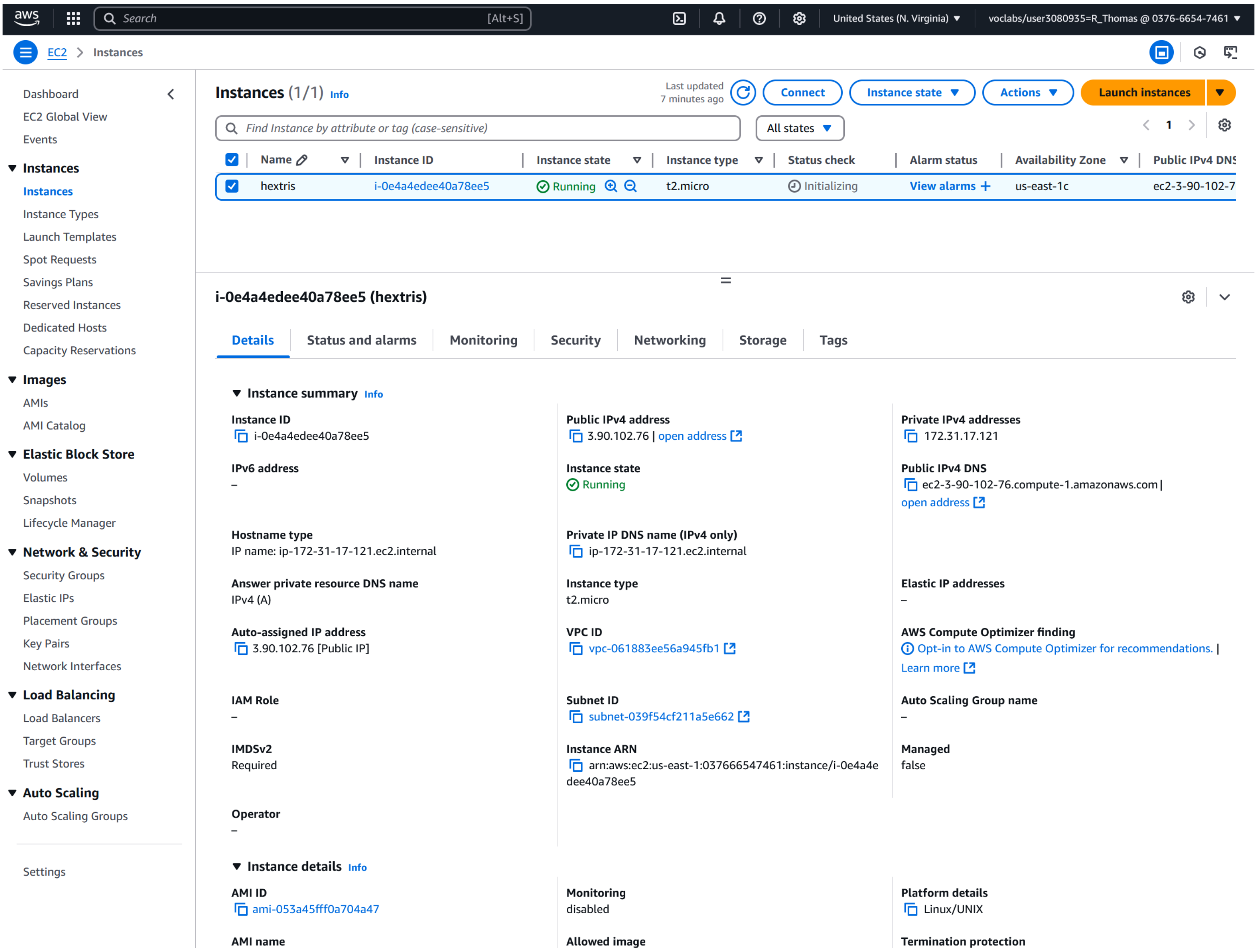
2.2 Instance Settings

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-053a45fff0a704a47`.
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.

3 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.



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 4 worked.

1. Return to the AWS Learner Lab interface.
2. In the terminal window 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
   ~~       V~' '->
    ~~~         /
      ~~._.   _/
         _/ _/
       _/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.

4 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 machine.

```
$ 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`.

5 Switching to Terraform

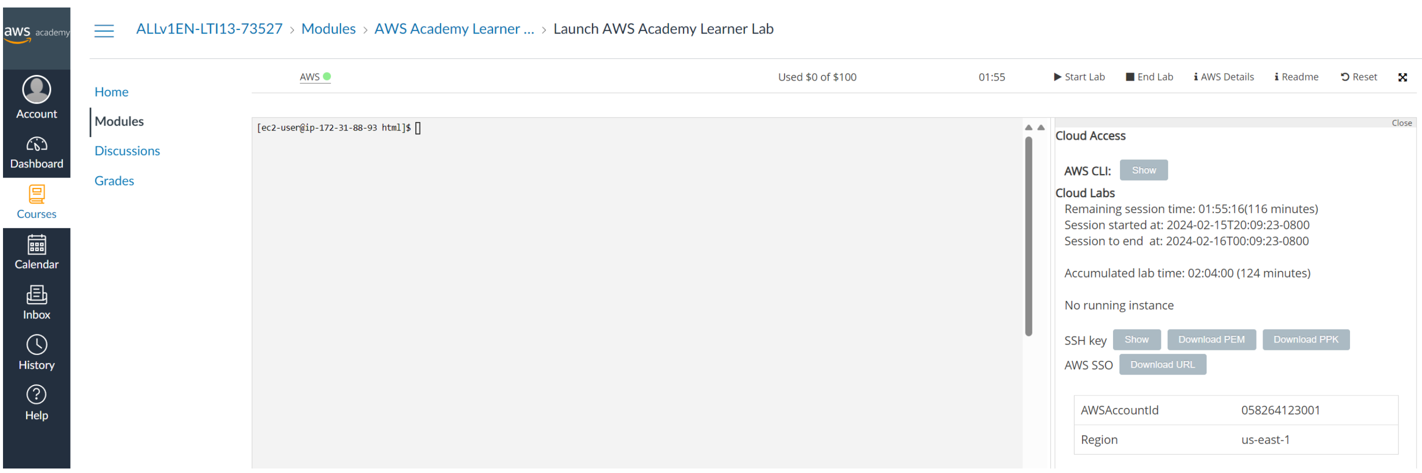
For the remainder of the practical we will use Terraform to provision the same instance we just created.

1. First, 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 with Terraform.

6 Using Terraform in AWS Learner Labs

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

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



2. Click on the first 'Show' button next to 'AWS CLI'. This will display a text block starting with `[default]`.

3. In the root directory of your repository, create a `credentials` file and copy the contents of the text block into the file. **Do <u>not</u> share this file contents — do <u>not</u> commit it**. This file is already in the `.gitignore` of your practical repository.

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 = "~> 6.0"
        }
    }
}

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 6.0. 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.

7 Deploying Hextris

First, we will need to create an EC2 instance resource. The AWS provider calls this resource an `aws_instance`[4]. 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.

```
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 = {
```

[4] https://registry.terraform.io/providers/hashicorp/aws/latest/docs/resources/instance

```
        + "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 4, we will produce the following 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.

7.1 Terraform Output

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.

```
» cat main.tf
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"
```

The output can be formatted using Terraform's string interpolation. We can use this to output the Hextris server's URL, rather than just its IP address.

```
» cat main.tf
output "hextris-url" {
  value = "http://${aws_instance.hextris-server.public_ip}/"
}
```

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

We can use the `terraform output` command to return the value of output variables. We can specify which variable(s) to return and the format in which they are returned. We can use this to obtain the Hextris server URL in a format that can be pasted directly into a browser. This can be run anytime after applying the plan.

```
$ terraform output -raw hextris-url
http://52.23.187.96/
```

Here we have specified to return the value of the `hextris-url` variable, without any formatting. So let's try and access that URL, hmm. That is strange. Something has gone wrong.

8 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 egress[5] 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).[6] 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"]
  }
}
```

[5] Ingress and egress in networking just mean incoming and outgoing respectively.

[6] We 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 4.

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.

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

Next, we will attach the security group to the EC2 instance. In the `aws_instance.hextrix-server` resource, 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 paste the URL into a web browser (the IP address may have changed), you should be able to view the Hextris website.

9 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 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!

Notice

Destroy everything again before you finish and close your Learner Lab. Anything left running in your lab may continue to consume your credit.

10 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.

11 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 are 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 = "vockey"
  user_data = file("./serve-hextris.sh")
  security_groups = [aws_security_group.hextris-server.name]

  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 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.

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.

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