Terraform State

Module Topics

- Understanding terraform state
- Managing state with terraform state commands
- Local state backend risks
- Using workspaces to multiple configurations
- Remote backends - using AWS S3
- Migrating state backends

What Is Terraform State?

- Terraform state refers to the record terraform keeps of the resources it has created
- The state file:
  - Creates a mapping between what was specified in the *tf files and deployed AWS resources
  - Stores metadata and configuration information
- When *terraform plan* is run, it does the following
  - Reads all of the *.tf files in a directory
  - Updates the state information to record modifications from the *.tf files
  - Queries AWS to get a description the current state of the deployed resources
  - Creates a plan to modify the AWS resources to conform to the state descriptions
- Terraform cannot see or modify AWS resources that are not in its state file

Terraform Planning

- When *terraform plan* is run
  - All files in the current directory with the .tf extension are read, and their contents are merged
  - Terraform develops a plan for implementing the specified configuration
- A directed acyclic graph of operations is created to ensure that all dependencies are resolved
  - The resources may need to be created in a specific order
- Thus means we can sort organize our code anyway we want
- However, there is usually a standard way to do this - i.e. the canonical form introduced in the last module

Terraform is Declarative

- Declarative means that you only describe the final state that you want your AWS resources to be in
- After you run *terraform apply* you will see the output in *terraform.tfstate*

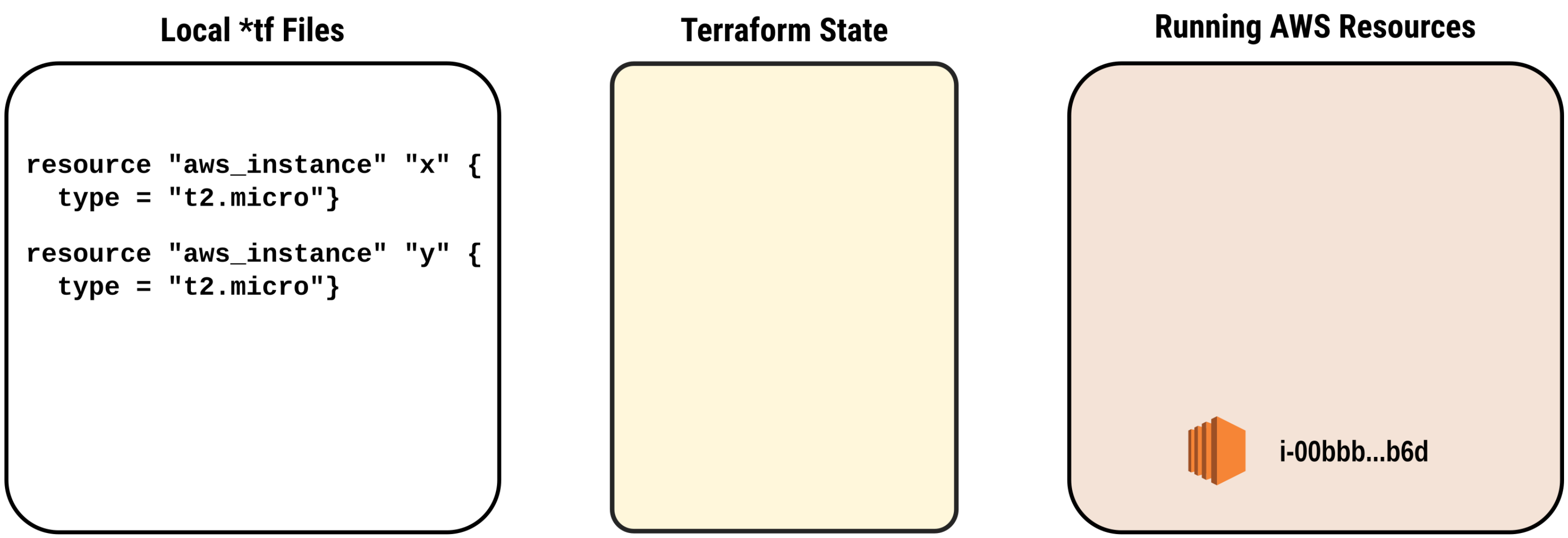

```json
{
  "version": 4,
  "terraform_version": "0.12.0",
  "serial": 1,
  "lineage": "1f2087f9-4b3c-1b66-65db-8b78faafc6fb",
  "outputs": {},
  "resources": [
    {
      "mode": "managed",
      "type": "aws_instance",
      "name": "example",
      "provider": "provider.aws",
      "instances": [
        {
          "schema_version": 1,
          "attributes": {
            "ami": "ami-0c55b159cbfafe1f0",
            "availability_zone": "us-east-2c",
            "id": "i-00d689a0acc43af0f",
            "instance_state": "running",
            "instance_type": "t2.micro",
            "(...)": "(truncated)"
          }
        }
      ]
    }
  ]
}
```

Meaning of the "terraform.tfstate" on Previous Slide

- Resource with *type aws_instance* and *name example* corresponds to an EC2 Instance in the AWS account with ID i-00d689a0acc43af0f
- Every time you run Terraform
  - it can fetch the latest status of this EC2 Instance from AWS
  - compare that to what’s in your Terraform configurations
  - determine what changes need to be applied
- Thus, the output of the *terraform plan* command is a diff
  - between the code on your computer and
  - the infrastructure deployed in the real world, as discovered via IDs in the state file

Example - Understanding State

- In this example, we have defined two EC2 instances "x" and "y" in our main.tf file
  - Since terraform plan hasn't been run, there is no terraform state
  - Note there is already a running EC2 instance in our AWS account



Before "terraform plan"

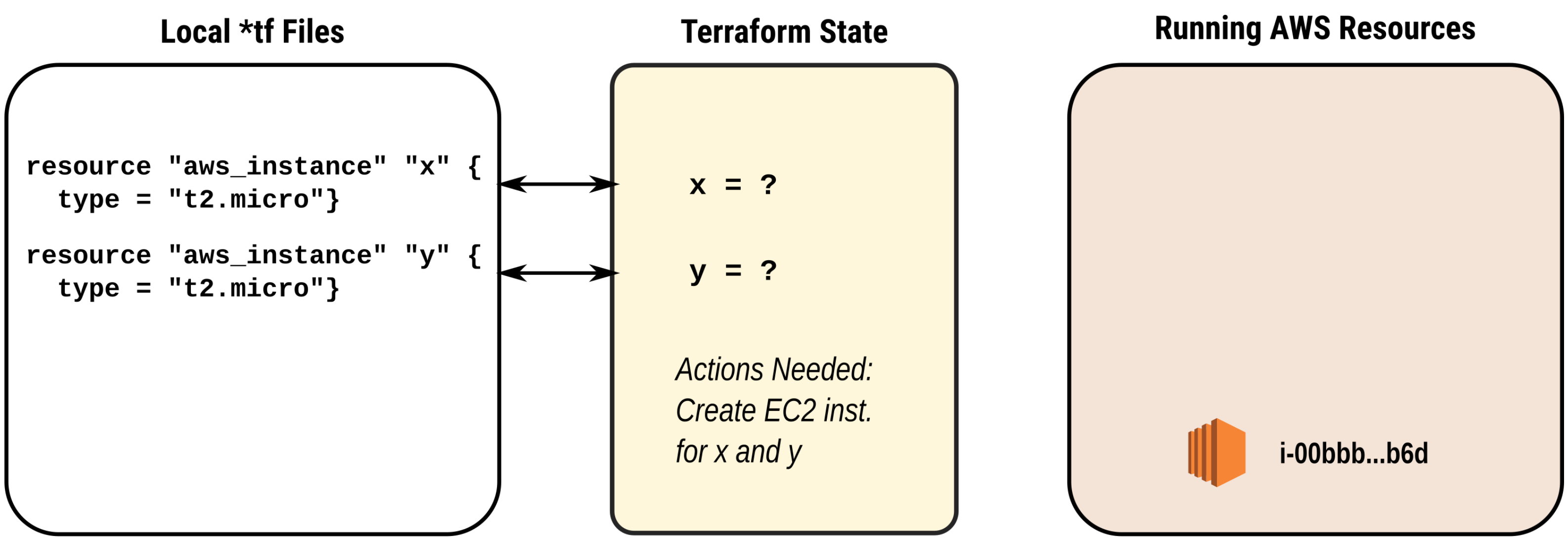
Example - Understanding State - The code

- This screenshot shows the code being used for this example

```
# Example 03-01

resource "aws_instance" "X" {
    ami = "ami-077e31c4939f6a2f3"
    instance_type = "t2.micro"
    tags = {
        Name = "Instance X"
    }
}

resource "aws_instance" "Y" {
    ami = "ami-077e31c4939f6a2f3"
    instance_type = "t2.micro"
    tags = {
        Name = "Instance Y"
    }
}
```

Example: The Plan Operation

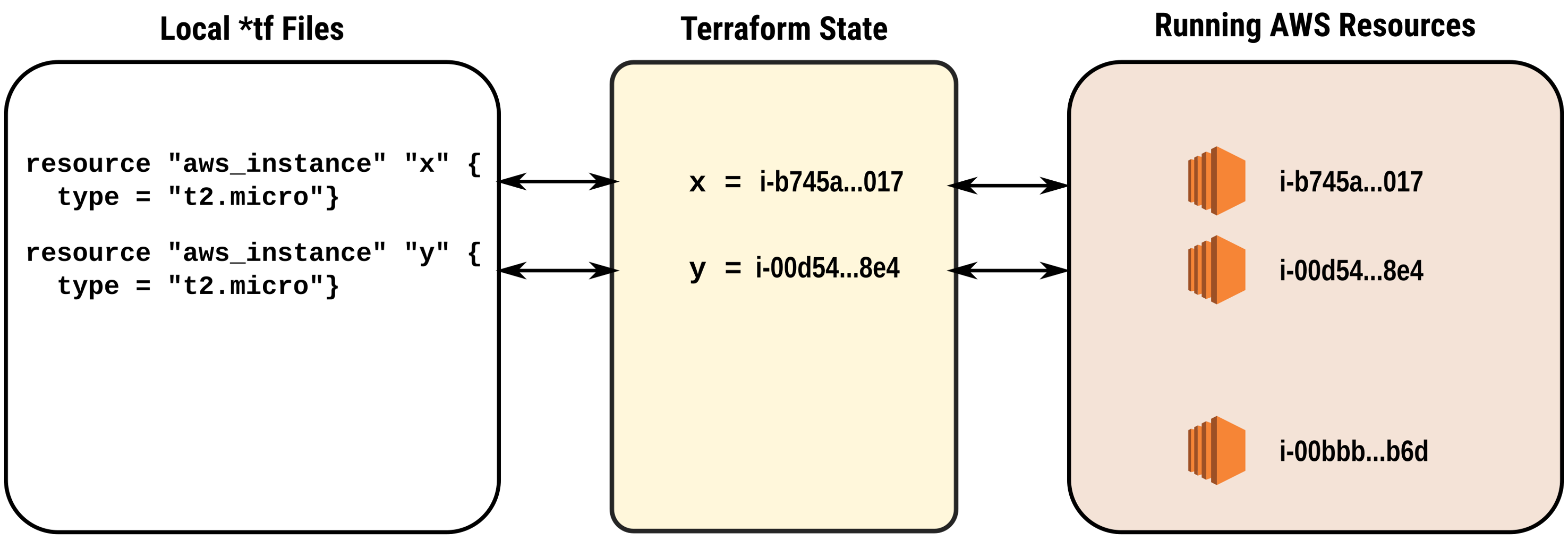
- After running *terraform plan* there are two resources without corresponding AWS instances
  - Terraform writes an action plan that will bring the AWS environment into alignment with the terraform state
  - If actions must be done in a particular order, terraform will determine the correct sequence



After"terraform plan"

Example: After the Apply Operation

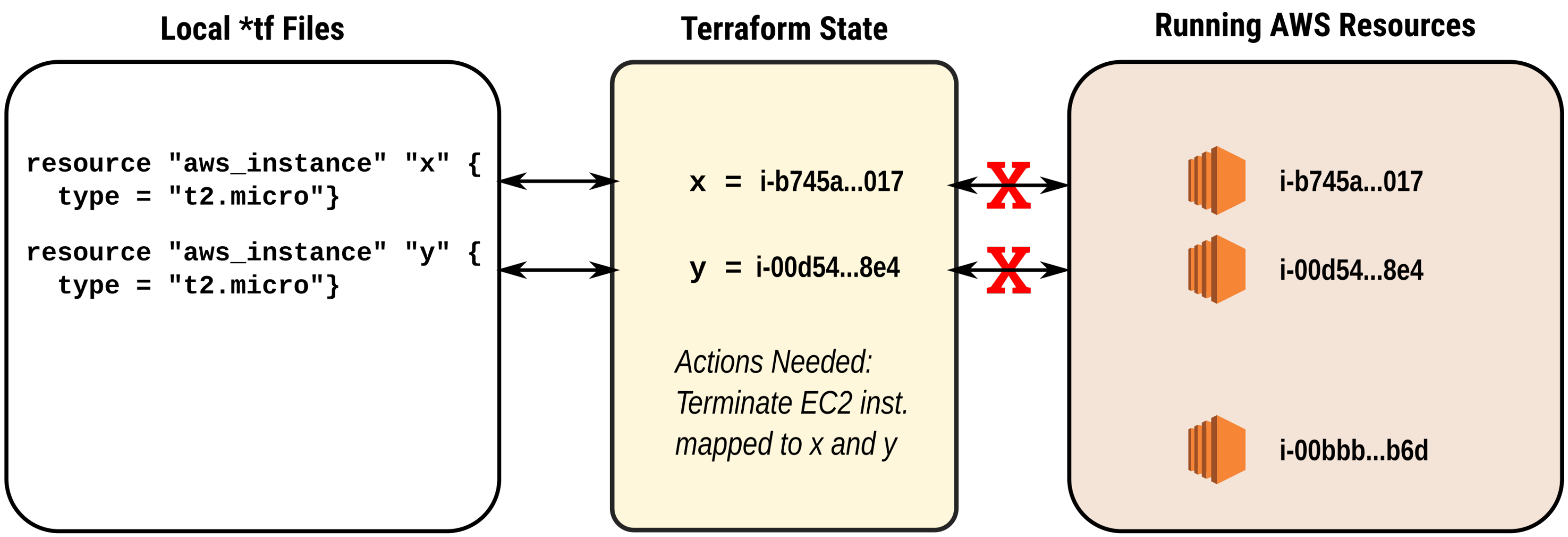
- The required modifications are made to AWS and the results stored in the state file



After "terraform apply"

Example: Planning the Destroy Operation

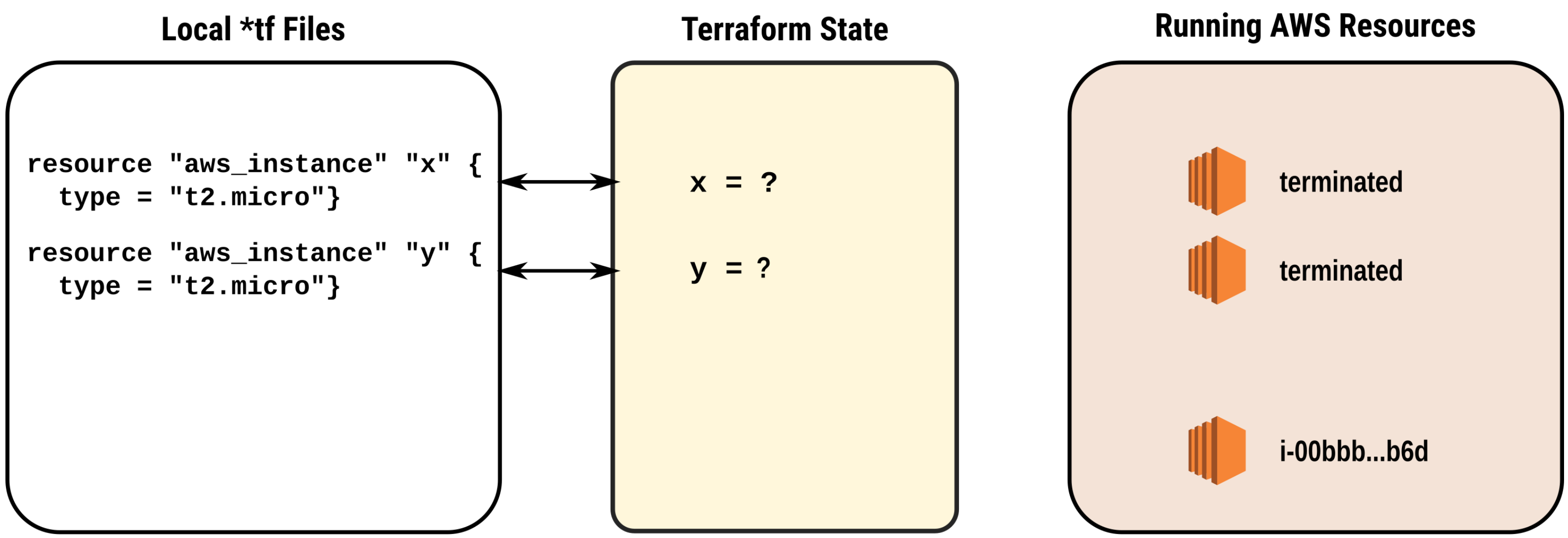
- The only resources that will be destroyed are the ones that are actually in the terraform state file
  - Terraform plans the actions to terminate the resources it is managing
  - A with apply, terraform will determine the correct sequence for removing resources



Plan for "terraform destroy"

Example: After the Destroy Operation

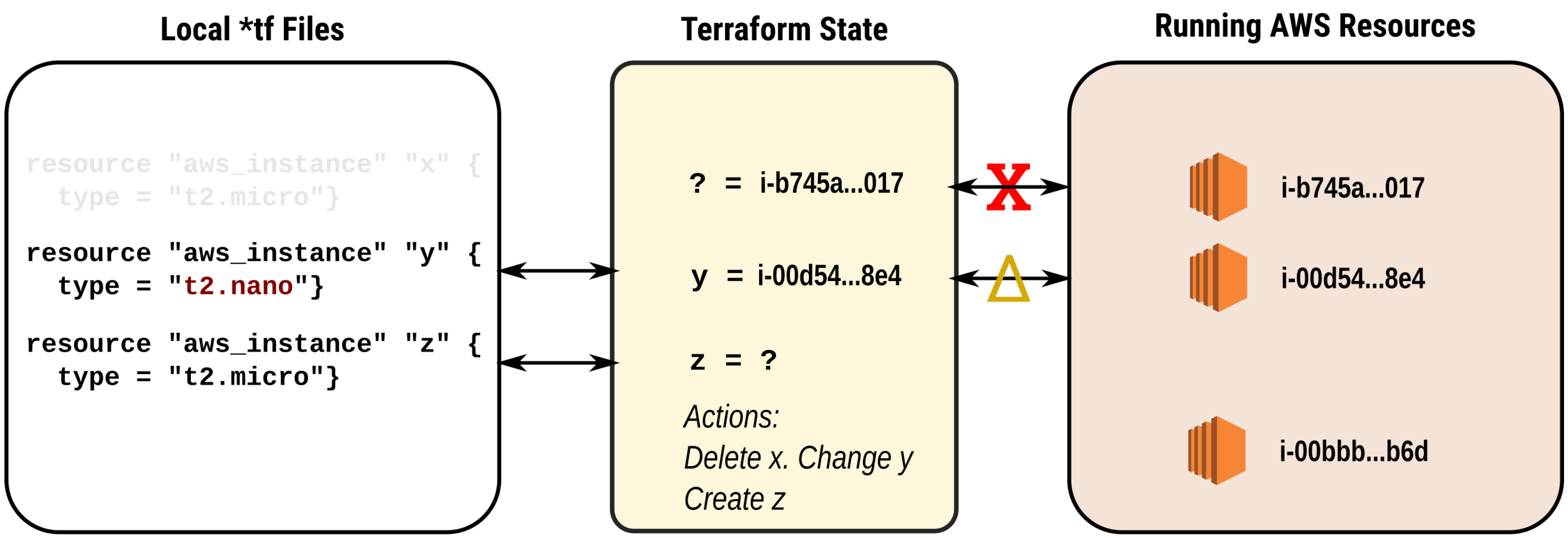
- Any resources not listed in the terraform state are left untouched



After "terraform destroy"

Modifying a Resource

- Changes to the *tf files are translated into actions by *terraform apply*
  - Removing a resource from the file causes its deletion from AWS and the state file
  - Adding a resource to the file causes it be created
  - Changing parameters of a resource causes it to be modified
  - **If a resource cannot be modified (eg. changing the ami) then the existing resource is destroyed and new resource created**



After "terraform plan"

Lab 3-1

- Please do Lab 3-1

The "state" Commands

- The state command has multiple options (not all are listed)
  - *terraform state list* : lists the resources being managed
  - *terraform state show <resource>* : displays state data for a resource
  - *terraform state rm <resource>* : stops managing the AWS object linked to <*resource*>
  - *terraform state mv* : renames a resource in the state file
- *terraform import <resource> <AWS ID>*: links the Terraform resource with a terraform resource

State Command Example

- The following is the environment defined for the example:

```
# Example 03-01

resource "aws_instance" "X" {
    ami = "ami-077e31c4939f6a2f3"
    instance_type = "t2.micro"
    tags = {
        Name = "Instance X"
    }
}

resource "aws_instance" "Y" {
    ami = "ami-077e31c4939f6a2f3"
    instance_type = "t2.micro"
    tags = {
        Name = "Instance Y"
    }
}
```

The "state list" Command

- The *state list* command lists all the resources being managed by the state file

```
C:\home\terraform>terraform state list
aws_instance.X
aws_instance.Y
```

The "state show" command

- The *state show <id>* displays the state file JSon data for that resource

```
C:\home\terraform>terraform state show aws_instance.X
# aws_instance.X:
resource "aws_instance" "X" {
    ami                                  = "ami-077e31c4939f6a2f3"
    arn                                  = "arn:aws:ec2:us-east-2:983803453537:ins
    associate_public_ip_address          = true
    availability_zone                    = "us-east-2c"
    cpu_core_count                       = 1
    cpu_threads_per_core                 = 1
    disable_api_termination              = false
    ebs_optimized                        = false
    get_password_data                    = false
    hibernation                          = false
    id                                   = "i-087c4d43d292c1c1b"
    instance_initiated_shutdown_behavior = "stop"
```

The "state rm" Command

- The rm command removes a specific resource from the state file
- In our example, we can remove the instance "X" from the state file
  - This means that the AWS resource is now no longer managed by terraform

```
C:\home\terraform>terraform state list
aws_instance.X
aws_instance.Y

C:\home\terraform>terraform state rm aws_instance.X
Removed aws_instance.X
Successfully removed 1 resource instance(s).

C:\home\terraform>terraform state list
aws_instance.Y
```

  - If *terraform apply* is run again, a new version of aws_instance.X will be created because terraform can no longer 'see' the AWS instance it previously created

The "terraform import" Command

- This is the converse of the "state rm" command by moving an existing AWS resource into a state file
- There must be a terraform resource specification with parameters that match the properties of the existing AWS resource
- In this example, we add back aws_instance.X that we just removed

```
C:\home\terraform>terraform state list
aws_instance.Y

C:\home\terraform>terraform import aws_instance.X i-087c4d43d292c1c1b
aws_instance.X: Importing from ID "i-087c4d43d292c1c1b"...
aws_instance.X: Import prepared!
  Prepared aws_instance for import
aws_instance.X: Refreshing state... [id=i-087c4d43d292c1c1b]

Import successful!

The resources that were imported are shown above. These resources are now in
your Terraform state and will henceforth be managed by Terraform.


C:\home\terraform>terraform state list
aws_instance.X
aws_instance.Y
```

The "state mv" Command

- This command allows us to link an existing AWS resource to a different terraform specification
  - For example, if we want to rename our EC2 instance from aws_instance.X to aws_instance.Z

```
resource "aws_instance" "X" {
    ami = "ami-077e31c4939f6a2f3"
    instance_type = "t2.micro"
    tags = {
        Name = "Instance X"
    }
}

resource "aws_instance" "Z" {
    ami = "ami-077e31c4939f6a2f3"
    instance_type = "t2.micro"
    tags = {
        Name = "Instance Z"
    }
}
```

The "state mv" Command

- Executing the " terraform state mv" command breaks the association between aws_instance.X and the AWS resource and then re-associates it with aws_instance.Z

```
C:\home\terraform>terraform state list
aws_instance.X
aws_instance.Y

C:\home\terraform>terraform state mv aws_instance.X aws_instance.Z
Move "aws_instance.X" to "aws_instance.Z"
Successfully moved 1 object(s).

C:\home\terraform>terraform state list
aws_instance.Y
aws_instance.Z
```

The "state mv" Command

- Running the "terraform plan" shows that two actions now have to be taken to update the AWS environment
  - The new instance "Z" has to be updated to change the tag from "Resource X" to "Resource Z"
  - Since there is no longer an AWS instance associated with aws_instance.Z, a new AWS instance will have to be created

```
C:\home\terraform>terraform plan
aws_instance.Y: Refreshing state... [id=i-09dd6f80869afb6cf]
aws_instance.Z: Refreshing state... [id=i-087c4d43d292c1c1b]

Terraform used the selected providers to generate the following execution plan.
 Resource actions are indicated with the
following symbols:
  + create
  ~ update in-place

Terraform will perform the following actions:

  # aws_instance.X will be created
  + resource "aws_instance" "X" {
      + ami                              = "ami-077e31c4939f6a2f3"
      + arn                              = (known after apply)
```

```
  # aws_instance.Z will be updated in-place
  ~ resource "aws_instance" "Z" {
        id                               = "i-087c4d43d292c1c1b"
      ~ tags                             = {
          ~ "Name" = "Instance X" -> "Instance Z"
        }
      ~ tags_all                         = {
          ~ "Name" = "Instance X" -> "Instance Z"
        }
```

Tainting and Untainting

- Occasionally, an AWS resource is created but is degraded or damaged, often because of a transient AWS problem
  - Although the resource is created, it is in a suspicious state and is marked by terraform as being tainted
  - A tainted resource will be recreated the next time *terraform apply* is run
- You can also manually taint a resource by running the *terraform taint* command if you feel the resource should be recreated
- Any tainted resource can be untainted by running the *terraform untaint* command

Tainting and Untainting

```
C:\home\terraform>terraform taint aws_instance.X
Resource instance aws_instance.X has been marked as tainted.

C:\home\terraform>terraform plan
aws_instance.X: Refreshing state... [id=i-0f16d218c41248b7e]
aws_instance.Y: Refreshing state... [id=i-09dd6f80869afb6cf]

Terraform used the selected providers to generate the following execution
plan. Resource actions are indicated with the following symbols:
-/+ destroy and then create replacement

Terraform will perform the following actions:

  # aws_instance.X is tainted, so must be replaced
-/+ resource "aws_instance" "X" {
```

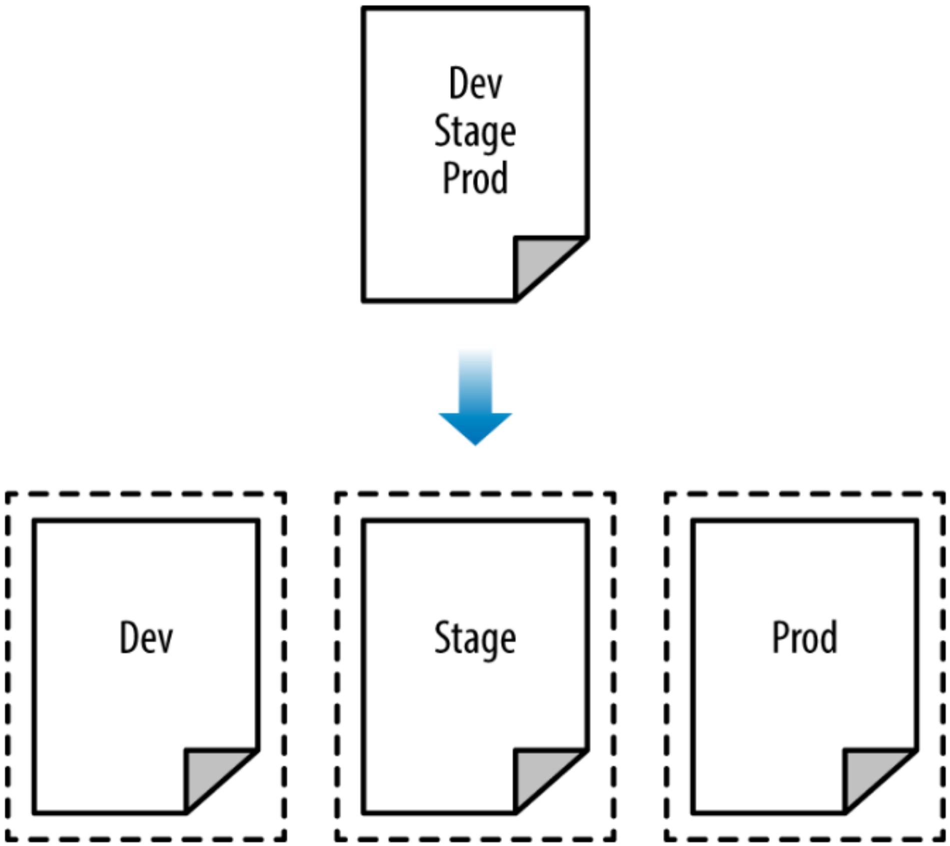
```
C:\home\terraform>terraform untaint aws_instance.X
Resource instance aws_instance.X has been successfully untainted.

C:\home\terraform>terraform plan
aws_instance.Y: Refreshing state... [id=i-09dd6f80869afb6cf]
aws_instance.X: Refreshing state... [id=i-0f16d218c41248b7e]

No changes. Infrastructure is up-to-date.
```

Lab 3-2

- Please do lab 3-2

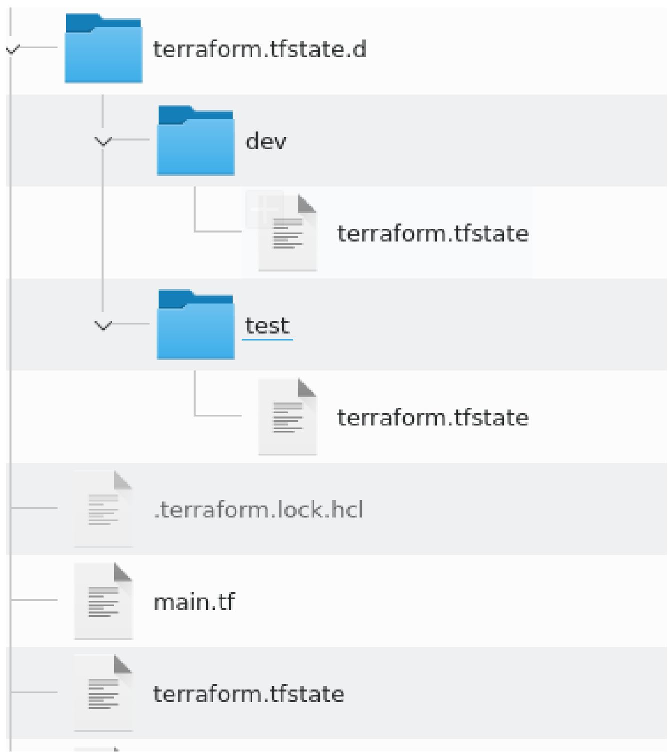
Separate Environments

- We often need multiple copies of a deployment for different purposes
- Common environments are: development, test, stage and production



Terraform Workspaces

- Terraform supports a separate configuration for each deployment
  - Each deployment is called a workspace
  - There is always a *default* workspace
- We can create additional workspaces as we need them
  - For example, we could have defined dev and test workspaces



The "workspace" Command

- *terraform workspace* has several options:
  - *list* : lists all workspaces marking the current one with "*"
  - *show* : lists the currently active workspace
  - *new <name>* : creates and switches to the newly created workspace
  - *select <name>* : switches to the named workspace
  - *delete <name>* : deletes the named workspace
    - The "default" workspace can never be deleted
    - Deleting a workspace does **not** destroy the resources, it just leaves them unmanaged

Managing State versus Managing IaC Code

- Workspaces manage the state information of different but related deployments
  - Often useful for a quick "what-if" type of analysis
- However, state information is **not** IaC code
- In order to support separate environments, there are two issues that must be managed
  - The states of the deployments - terraform does that for us
  - The organization of the IaC source code in the *tf files
- We have to manage the terraform source files exactly like we manage source code in standard development projects
  - For example, we can use a git-gitHub model and DevOps continuous integration

Local Backends and Workspaces

- The location of the terraform state files is called the "backend"
- When the state file is kept in the same directory as the *.tf files, then we are using what is called a local backend
  - This is the default for terraform "out of the box"
- Each workspace manages its own copy of the AWS resources, but they all use the same *tf files
  - The amount of "isolation" between our different workspaces or teams is quite low
  - For example, the *dev* group might make changes that break the *prod* configuration
- We often use workspaces when we want to spin up a copy of an environment without interfering with an existing deployment

Versioning Configurations

- A basic principle of IaC is that we treat our configuration files as code
- We can version our configuration by putting the *tf files in git or other vcs
  - We do **not** put the state files in version control
  - Unless we want to store snapshots of the state files
- If we make changes and break a configuration, we can roll back to a working version
- If we want to make changes in workspaces:
  - Commit the *tf files to a git repository
  - For each workspace used, create a corresponding git branch
  - As you switch workspaces, switch branches
- This still does not fix the problems with the state files
  - *"Oops, I forgot to check out the dev branch and destroyed the production configuration"*

Lab 3-3

- Please do Lab 3-3

Problem with Local Backends

- Shared storage for state files
  - Files need to be in common shared area so everyone on the team can access them
  - Without file locking, race conditions when concurrent updates to the state files take place
  - This can lead to conflicts, data loss, and state file corruption
  - Even if we use versioning, branches and workspaces
- Isolation
  - It's difficult to isolate the code used in different environments
  - Lack of isolation makes it easy to accidentally overwrite environments
  - The problem that we cannot address locally is that the state file is a shared resource
  - Even if the *tf source files are isolated from each other
- Secrets
  - Confidential information is stored in the clear (i.e. AWS Keys)

Remote Backends

- Each Terraform configuration has a location where the state files are kept
  - This is called the "backend"
  - The default is to use files in the local directory
  - Even using git or another system does not address the problems mentioned
- Terraform can also support "remote" backends
  - For example, we can keep state files in an S3 bucket on AWS
  - Not all providers can host remote back ends

Remote AWS Backend

- Using S3 as a backend resolves many of these issues
  - S3 manages the updating and access independently, and supports versions
  - S3 supports encryption
  - S3 supports locking for multiple access
  - S3 allows a common repository we can control access to
- S3 is also managed so that we don't have to manage it
  - S3 has high levels of availability and durability
  - S3 also means we have reduced the risk of "loosing" configurations

Setting up the S3 Bucket

```
resource "aws_s3_bucket" "terraform_state" {
    bucket = "terraform-up-and-running-state"

    # Prevent accidental deletion of this S3 bucket
    lifecycle {
        prevent_destroy = true
    }

    # Enable versioning so we can see the full revision history of our
    # state files
    versioning {
        enabled = true
    }

    # Enable server-side encryption by default
    server_side_encryption_configuration {
        rule {
            apply_server_side_encryption_by_default {
                sse_algorithm = "AES256"
            }
        }
    }
}
```

Setting up the Locking Table

- Next, a DynamoDB table to use for locking
  - DynamoDB is Amazon's distributed key–value store
  - It supports strongly consistent reads and conditional writes

```
resource "aws_dynamodb_table"  "terraform_locks" {
    name         = "terraform-up-and-running-locks"
    billing_mode = "PAY_PER_REQUEST"
     hash_key     = "LockID"

    attribute {
        name = "LockID"
        type  = "S"
    }
}
```

The Backend for the Remote Backend

- When we set up the remote backend, we create a state file that describes the configuration of the remote backend
- **The remote backend state file is not kept in the remote backend**
  - We keep the remote backend state file separate and secure
  - Locked down and accessible only to the configuration manager
- We can have multiple S3 back ends for different projects
  - The state files for each S3 backend are kept in a master S3 backend
  - But the state of the master S3 backend is stored securely somewhere else

Setting Up the Backend

- We have to tell Terraform the backend in now remote
  - We do this in the *terraform* directive
  - The key creates a unique folder in the S3 bucket for this state file

```
terraform {
    backend "s3" {
        # Replace this with your bucket name!
        bucket         = "terraform-up-and-running-state"
        key            = "mykey" #
        region         = "us-east-2"

        # Replace this with your DynamoDB table name!
        dynamodb_table = "terraform-up-and-running-locks"
        encrypt        = true
    }
}
```

Moving State File Locations

- To move local state to a remote backend
  - Create the remote backend resources and define the backend configuration
  - Run *terraform init* and the local config is copied to the remote backend
- To move from remote backend to a local backend
  - Remove the backend configuration
  - Run *terraform init* and the remote config is copied to the local backend

Moving Backends Summary

- To make this work, you need to use a two-step process:
  - Create the S3 bucket and DynamoDB table and deploy that code with a local backend
  - Add a remote backend configuration to it to use the S3 bucket and DynamoDB table
  - Run terraform init to copy your local state to S3
- To revert to a local state backend
  - Remove the backend configuration
  - Rerun terraform init to copy the Terraform state to the local disk
  - Run terraform destroy to delete the S3 bucket and DynamoDB table

Remote Backend Advantage

- A single S3 bucket and DynamoDB table can be shared across all your Terraform code
- You'll probably only need to do it once per AWS account
- After the S3 bucket exists, in the rest of your Terraform code, you can specify the backend configuration right from the start without any extra steps

Backend Limitation

- Variables and references cannot be used in the `backend` block
- The following will **not** work

```
# This will NOT work. Variables aren't allowed in a backend configuration.
terraform {
    backend "s3" {
        bucket         = var.bucket
        region         = var.region
        dynamodb_table = var.dynamodb_table
        key            = "example/terraform.tfstate"
        encrypt        = true
        }
}
```

File Isolation

- Most secure approach is to have a folder for each configuration
  - Each folder can maintain its own version control for the *tf files
  - Or a common repository can be used
  - Remember that the *tf files are *source code*
- Each deployment has its own backend, local or remote.
  - This allows for isolation of all files
  - Allows for different access and authentication mechanisms
  - Eg. Different S3 buckets used as backends can have different policies

File Isolation Example

- stage
  - vpc
  - services
    - frontend-app
    - backend-app
      - variables.tf
      - outputs.tf
      - main.tf
  - data-storage
    - mysql
    - redis
- prod
  - vpc
  - services
    - frontend-app
    - backend-app
  - data-storage
    - mysql
    - redis
- mgmt
  - vpc
  - services
    - bastion-host
    - jenkins
- global
  - iam
  - s3

Workspaces Use Case

- If you already have a Terraform module deployed
  - you want to do some experiments with it
  - but you don't want your experiments to affect the state of the already deployed infrastructure
- Run *terraform workspace new* to deploy a new copy of the exact same infrastructure, but storing the state in a separate file

Workspace Specific Configurations

- You can even change how that module behaves based on the workspace you're in by reading the workspace name using the expression `terraform.workspace`

```
resource "aws_instance" "example" {
    ami           = "ami-0c55b159cbfafe1f0"
    instance_type = terraform.workspace == "default" ? "t2.medium" : "t2.micro"
}
```

- Workspaces allow a fast and easy way o quickly spin up and tear down different versions of your code

Workspace Drawbacks

- All workspace state files are stored in the same backend
  - They share same authentication and access controls which means they are not good for isolating
- Workspaces are not visible in the code or on the terminal unless you run terraform workspace commands
  - A module in one workspace looks exactly the same as a module deployed in 10 workspaces
  - This makes maintenance more difficult, because you don't have a good picture of your infrastructure
- Workspaces can be fairly error prone
  - The lack of visibility makes it easy to forget what workspace you're in and accidentally make changes in the wrong one

Isolation via File Layout

- To achieve full isolation between environments:
  - Put the Terraform configuration files for each environment into a separate folder
  - For example, all the configurations for the staging environment can be in a folder called stage
  - All the configurations for the production environment can be in a folder called prod
- Configure a different backend for each environment, using different authentication mechanisms and access controls
  - Each environment could live in a separate AWS account with a separate S3 bucket as a backend

Typical Project File Layout

```
stage
    vpc
    services
        frontend-app
        backend-app
            variables.tf
            outputs.tf
            main.tf
    data-storage
        mysql
        redis
prod
    vpc
    services
        frontend-app
        backend-app
    data-storage
        mysql
        redis
mgmt
    vpc
    services
        bastion-host
        jenkins
global
    iam
    s3
```

Isolation via File Layout

- At the top level, there are separate folders for each "environment
  - **stage** : An environment for preproduction workloads (testing)
  - **prod** : An environment for production workloads (user facing apps)
  - **mgmt** : An environment for DevOps tooling (Jenkins etc.)
  - **global** : Resources that are used across all environments (S3, IAM)
- Within each environment, there are separate folders for each "component":
  - **vpc** : Network topology for this environment
  - **services** : Apps or microservices to run in this environment - each app could have its own folder to isolate it
  - **data-storage** : The data stores to run in this environment, such as MySQL or Redis

Isolation via File Layout

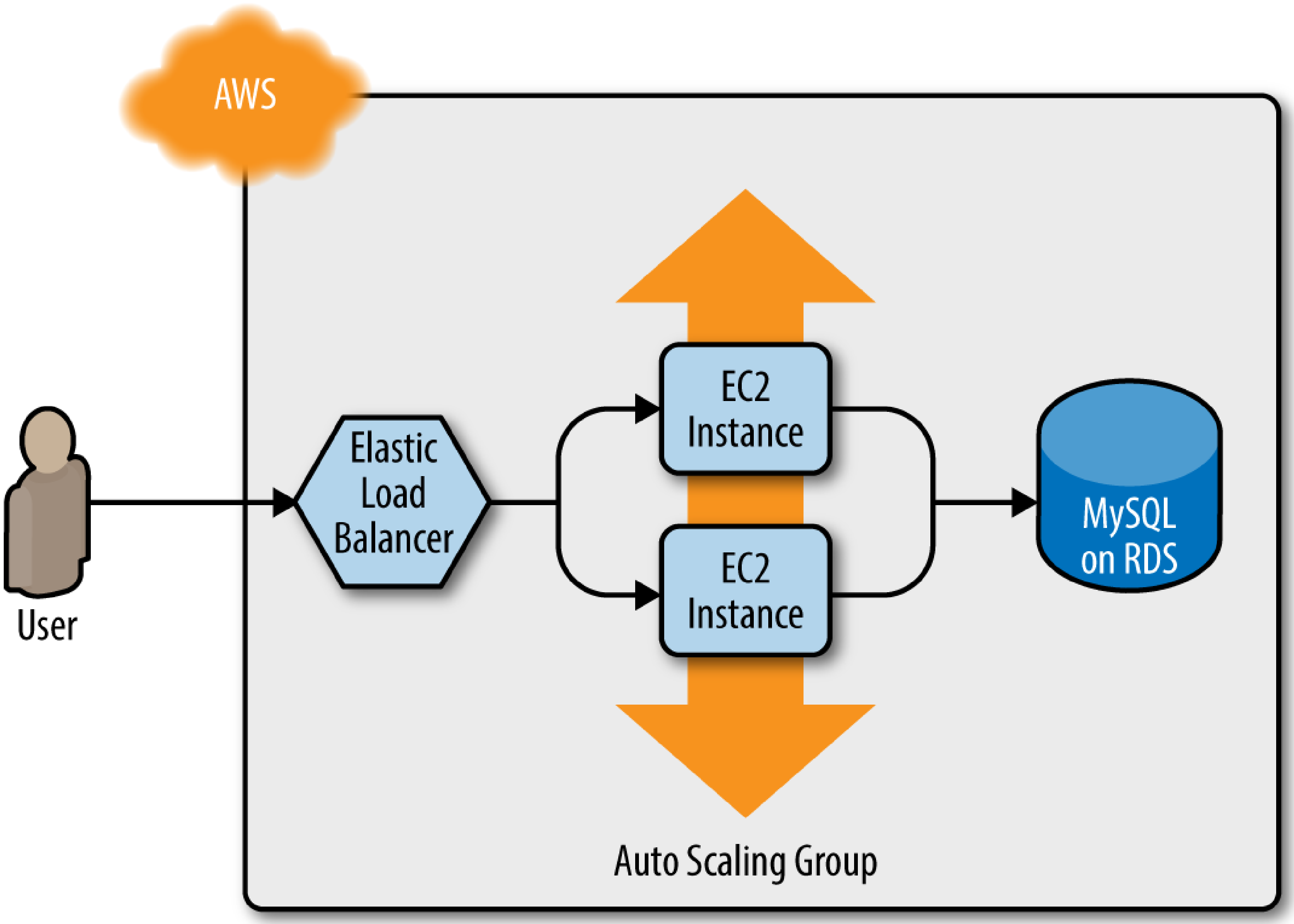
- Within each component are the actual Terraform configuration files with the following naming conventions:
  - **variables.tf** : Input variables
  - **outputs.tf** : Output variables
  - **main.tf** : The resources
- Terraform looks for files in the current directory with the .tf extension
  - Using a consistent, predictable naming convention makes code easier to browse
  - Then you always know where to look to find a variable, output, or resource. If individual Terraform files are

Rarranged Sample Code

```
stage
    services
        webserver-cluster
            variables.tf
            outputs.tf
            main.tf
global
    s3
        outputs.tf
        main.tf
```

The "terraform_remote_state" Data Source

- Assume that the web server cluster needs to communicate with a MySQL database



Deployment Consideration

- The MySQL database should probably be managed with a different set of configuration files as the web server cluster
  - Updates will probably be deployed to the web server cluster frequently
  - Want to avoid accidentally breaking the database when doing an update

Deployment Consideration

- Isolate the MySql configurations in a data-stores folder

```
stage
    services
        webserver-cluster
            variables.tf
            outputs.tf
            main.tf
    data-stores
        mysql
            variables.tf
            outputs.tf
            main.tf
global
    s3
        outputs.tf
        main.tf
```

Keeping Secrets I

- One of the parameters that you must pass to the *aws_db_instance* resource is the master password to use for the database
  - This should not be in the code in plain text
  - There are two other options
- Read the secret from a secret store - there are multiple secrets managers
  - AWS Secrets Manager and the aws_secretsmanager_secret_version data source (shown in the example code)
  - AWS Systems Manager Parameter Store and the aws_ssm_parameter data source
  - AWS Key Management Service (AWS KMS) and the aws_kms_secrets data source
  - Google Cloud KMS and the google_kms_secret data source
  - Azure Key Vault and the azurerm_key_vault_secret data source
  - HashiCorp Vault and the vault_generic_secret data source

Using AWS Secrets Manager

```
resource "aws_db_instance" "example" {
    identifier_prefix   = "terraform-up-and-running"
    engine              = "mysql"
    allocated_storage   = 10
    instance_class      = "db.t2.micro"
    name                = "example_database"
    username            = "admin"

    password = data.aws_secretsmanager_secret_version.db_password.secret_string
}

data "aws_secretsmanager_secret_version" "db_password" {
    secret_id = "mysql-master-password-stage"
}
```

Keeping Secrets II

- Other option is to manage them completely outside of Terraform
  - Then pass the secret into terraform via an environment variable.
  - In the code below, there is no default since it's a secret

```
variable "db_password" {
    description = "The password for the database"
    type        = string
}

export TF_VAR_db_password="(YOUR_DB_PASSWORD)"
$ terraform apply
```

- A known weakness of Terraform:
  - The secret will be stored in the terraform state file in plain text
  - The only solution is to lock down and ecrypt the state files

Final Notes

- Correct isolation, locking and state must be a priority
  - Bugs in a program only break a part of an app
  - Bugs in infrastructure can have catastrophic effects and result in whole systems crashing and becoming unworkable
- Infrastructure has to be planned and incrementally tested
  - We never code infrastructure "on the fly"
- We never experiment with infrastructure in a production environment
  - Always work in a sandbox
  - With IaaS, this is easily done

Lab 3-4

- Please do Lab 3-4