O'REILLY®

Hashicorp Certified: Terraform Associate Certification Crash Course

Curriculum Version 003

About the trainer

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AUTOMATED ASCENT

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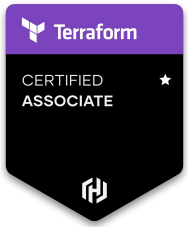
Certification Exam

Objectives, Curriculum, Prerequisites, Learning Resources

Exam Objectives

“Basic understanding of concepts and skills associated with open source HashiCorp Terraform and Cloud features.”



The certification program allows users to demonstrate their competence in a multiple choice test.

https://www.hashicorp.com/certification/terraform-associate

Curriculum Changes

Version 003 replaced 002 in May 2023

#	Objective Description	Status in Terraform Associate 003
3e	~~Explain when to use and not use provisioners and when to use local-exec or remote-exec~~	Removed
4	Use Terraform outside of core workflow	`terraform taint` removed, other topics reorganized
6b	Initialize a Terraform working directory (`terraform init`)	Includes questions about `terraform.lock.hcl`
7	Implement and maintain state	Cloud integration authentication, and cloud backends added
8a	Demonstrate use of variables and outputs	Covers sensitive variables and outputs' relationship to exposure on the CLI
8g	~~Configure~~ resource using a `dynamic` block	Use cases for `dynamic` block are still tested in objective 8
9	Understand Terraform Cloud capabilities	Restructured to accommodate the current and future state of Terraform Cloud

https://www.hashicorp.com/certification/terraform-associate-002

The Curriculum

1	**Understand infrastructure as code (IaC) concepts**
1a	Explain what IaC is
1b	Describe advantages of IaC patterns

2	**Understand the purpose of Terraform (vs other IaC)**
2a	Explain multi-cloud and provider-agnostic benefits
2b	Explain the benefits of state

3	**Understand Terraform basics**
3a	Install and version Terraform providers
3b	Describe plugin-based architecture
3c	Write Terraform configuration using multiple providers
3d	Describe how Terraform finds and fetches providers

4	**Use Terraform outside of core workflow**
4a	Describe when to use `terraform import` to import existing infrastructure into your Terraform state
4b	Use `terraform state` to view Terraform state
4c	Describe when to enable verbose logging and what the outcome/value is

5	**Interact with Terraform modules**
5a	Contrast and use different module source options including the public Terraform Module Registry
5b	Interact with module inputs and outputs
5c	Describe variable scope within modules/child modules
5d	Set module version

The Curriculum

6	Use the core Terraform workflow
6a	Describe Terraform workflow (Write -> Plan -> Create)
6b	Initialize a Terraform working directory (`terraform init`)
6c	Validate a Terraform configuration (`terraform validate`)
6d	Generate and review an execution plan for Terraform (`terraform plan`)
6e	Execute changes to infrastructure with Terraform (`terraform apply`)
6f	Destroy Terraform managed infrastructure (`terraform destroy`)
6g	Apply formatting and style adjustments to a configuration (`terraform fmt`)

7	Implement and maintain state
7a	Describe default `local` backend
7b	Describe state locking
7c	Handle backend and cloud integration authentication methods
7d	Differentiate remote state back end options
7e	Manage resource drift and Terraform state
7f	Describe `backend` block and cloud integration in configuration
7g	Understand secret management in state files

8	Read, generate, and modify configuration
8a	Demonstrate use of variables and outputs
8b	Describe secure secret injection best practice
8c	Understand the use of collection and structural types
8d	Create and differentiate `resource` and `data` configuration
8e	Use resource addressing and resource parameters to connect resources together
8f	Use HCL and Terraform functions to write configuration
8g	Describe built-in dependency management (order of execution based)

9	Understand Terraform Cloud capabilities
9a	Explain how Terraform Cloud helps to manage infrastructure
9b	Describe how Terraform Cloud enables collaboration and governance

Candidate Prerequisites

Basic Terminal Skills

Basic understanding of on premises and cloud architecture

Preparing for the Exam

Documentation is not allowed during the test

- Study Guide:
  https://learn.hashicorp.com/tutorials/terraform/associate-study
- Exam Review:
  https://learn.hashicorp.com/tutorials/terraform/associate-review
- Sample Questions:
  https://learn.hashicorp.com/tutorials/terraform/associate-questions

Infrastructure as Code (IaC)

Concepts and Benefits

Infrastructure as Code (IaC)

Manage infrastructure with the help of code

- Treats all aspects of operations as software via configuration
- Code is tracked in a SCM repository
- Automation makes the provisioning process consistent, repeatable, and updates fast & reliable

Repeatable Process

Clear instructions that describe the desired state

- A set of instructions are defined with the help of a declarative language
- Operations are idempotent e.g. an update to the environment will only make necessary changes but not duplicate what already exists
- **Example:** A database was deployed with a port but the port needs to change. We can simply change the port number in the code we used to deploy the database in the first place.

Consistent Environments

Environment should look extremely similar

- Projects often use a variety of deployment environments e.g. development, staging, and production
- The same automation code can be used to provision infrastructure so that it looks consistent across all environments
- **Example:** Deploying an EC2 server across all environments but with slightly different regions

Reusable Functionality

Configuration can be abstracted and applied to a set of projects

- Configuration is defined with the help of code
- Code can be shared across different repositories
- **Example:** Deploying a HTTP web server for multiple projects with the same piece of code.

Self-Documenting

Source code represents the architecture

- Each piece of infrastructure has been described with a set of instructions
- No more guesswork on what configuration has been used to provision infrastructure
- **Example:** New engineering team members can read source code to understand how infrastructure is configured

Financial Savings

Increased efficiency, less mistakes through automation

- Reduced risk due to minimizing human error
- Infrastructure can be verified with automated tests
- IaC functions can be used to spin down environments during times of less traffic
- **Example:** Decrease the manual grunt work for DevOps personnel and spending it on mission-critical tasks instead

Q & A

Terraform 101

What is Terraform and How Does it Implement IaC?

What is Terraform?

Infrastructure automation tool

- Open source and cloud provider-agnostic
- Configuration is expressed in a declarative language with either HashiCorp Configuration Language (HCL) or JSON
- Deployment of infrastructure happens with a push-based approach (no agent to be installed on remote machines)

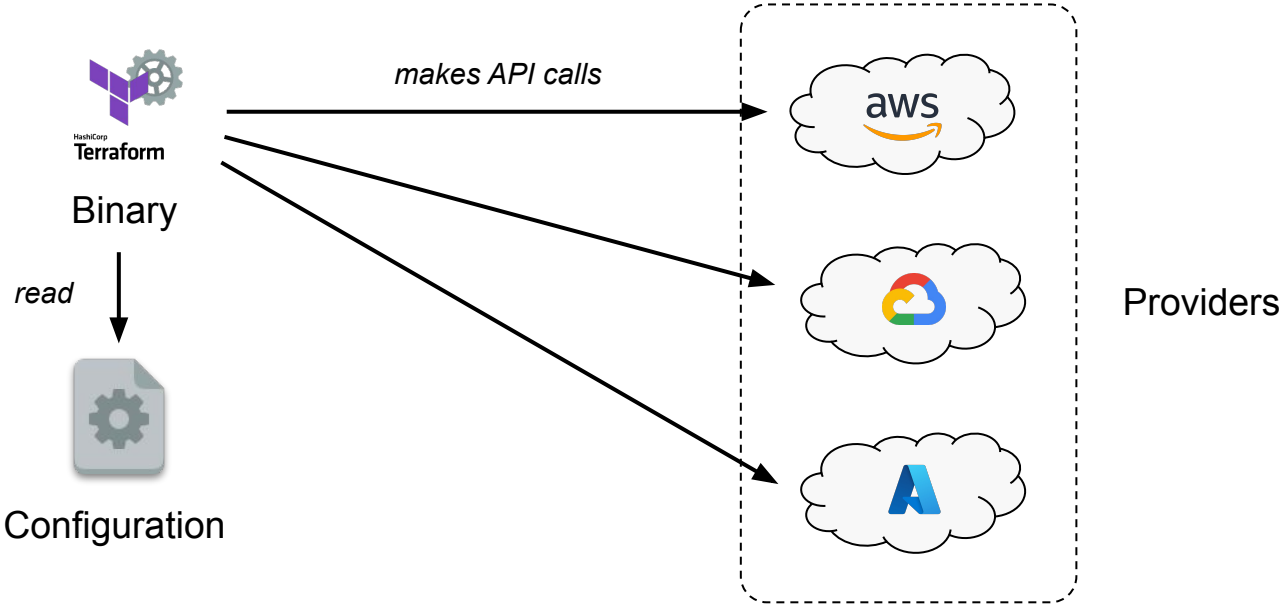
How Does Terraform Work?

Binary makes API calls to cloud providers

- CLI tool for deploying infrastructure to one or many cloud provider(s) e.g. AWS, Azure, or Google Cloud
- Under the hood, makes API calls on behalf of a *provider* including authentication mechanisms
- Terraform *configurations* are the codified instructions in the form of a text file that tell it which API calls to make

Interaction with Cloud Providers

Binary makes API calls to cloud providers



Cloud Provider Portability

Features are different, Terraform's technical approach is not

- Cloud providers don't support the exact same infrastructure
- Terraform allows you to use the same approach to define provider-specific configuration
- You use the same Terraform language, toolset, and IaC practices

Terraform Components

Key building blocks in architecture

- *Executable:* Binary run from the command line that contains Terraform's core functionality
- *Configuration file(s):* Files with the extension `.tf` or `.tfvars` that define the desired configuration for provisioning infrastructure
- *Provider plugins:* Executables invoked by Terraform to interact with cloud provider APIs, hosted on a registry
- *State data:* The desired configuration and its current state

Persisting State

Knows what has been created before and applies changes


```
resource "aws_instance" "example" {
  count         = 2
  ami           = "ami-0c55b159cbfafe1f0"
  instance_type = "t2.micro"
}
```

```
resource "aws_instance" "example" {
  count         = 3
  ami           = "ami-0c55b159cbfafe1f0"
  instance_type = "t2.micro"
}
```

State Storage

Where and how is state stored and updated?

- Stores state in internal database, each resource is represented by an key-value pair in the entry
- Any changes to the resources will be reflected in the state
- Locally, the state is saved in the file `terraform.tfstate`
- Remote state handling exists to support consistent team collaboration

Benefits of State

Keeping state fulfills important requirements

- *Dependencies:* Resources can have dependencies on each other, Terraform retains this metadata to be able to safely perform operations e.g. delete

- *Performance:* Terraform stores a cache of the attribute values for all resources in the state for performance reasons

- *Consistency:* Terraform employs locking to avoid synchronization and collaboration issues

Terraform and Ansible

Differences and use cases

- **Ansible:** Configuration management tool for installing/configuring software and tools in the infrastructure
- **Terraform:** May invoke Ansible after infrastructure as been deployed
- When to involve Ansible?
  - You already have Ansible playbooks you want to invoke
  - Nowadays, it's more common to create an immutable image that already contains the software needed

Terraform and Packer

Differences and use cases

- **Packer:** Creates machine images for multiple platforms
- **Terraform:** Uses machine image to provision infrastructure
- When to involve Packer?
  - To shorten deployment time by baking needed functionality into AMI
  - To simplify or avoid logic in Terraform needed for installing additional tooling, monitoring, logging etc. on top of base AMI

Terraform and Consul

Do I need to involve a state backend?

- **Terraform** can store state data in a backend to improve team collaboration

- **Consul** is one of the configurable backends supported by Terraform. Effectively, it's a key-value store installed on a dedicated server

- When to involve Consul?
  - When your team works on Terraform configuration in parallel and runs into potential conflicts a lot
  - If you do not want to buy into Terraform Cloud

Q & A

Terraform Installation and Configuration

Binary Installation, AWS Account, IDE Support

Installing Terraform

Easy to install on all operating systems

- Manual installation
  - Download ZIP file containing the pre-compiled binary
  - Add binary to `PATH` environment variable

- Using a package manager
  - Available via Homebrew and Chocolatey
  - Takes care of adding binary to terminal

Verifying and Using Terraform

The `terraform` executable is the main entry point

```
$ terraform version
Terraform v1.3.1
on darwin_amd64
```

```
$ terraform -help
Usage: terraform [global options] <subcommand> [args]

The available commands for execution are listed below.
The primary workflow commands are given first, followed by
less common or more advanced commands.

Main commands:
  init          Prepare your working directory for other commands
  validate      Check whether the configuration is valid
  plan          Show changes required by the current configuration
  apply         Create or update infrastructure
  destroy       Destroy previously-created infrastructure

...
```

Switching Between Versions

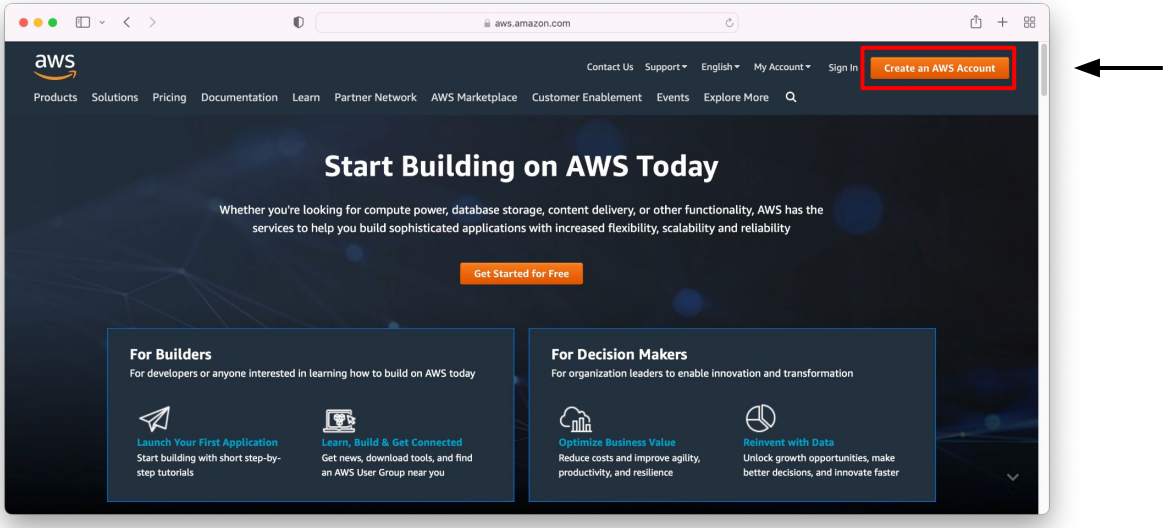
tfswitch lets you manage and use versions in parallel


```
$ tfswitch 1.2.1
$ terraform version
Terraform v1.2.1
on darwin_amd64

$ tfswitch 1.3.2
$ terraform version
Terraform v1.3.2
on darwin_amd64
```

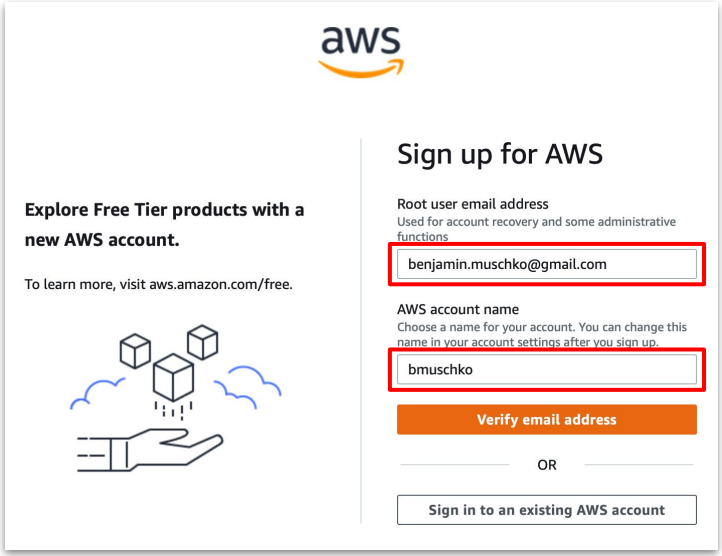
Setting Up an AWS Account

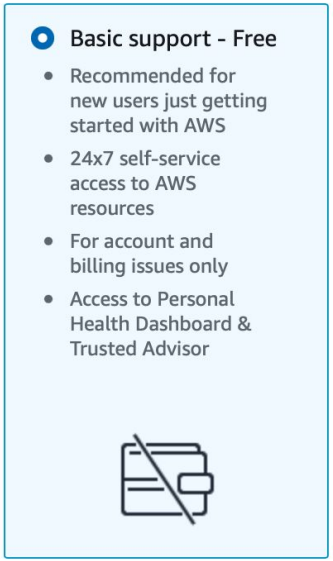
Create new account at https://aws.amazon.com

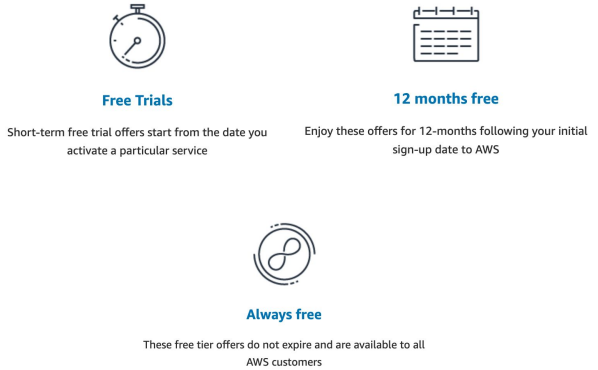


Setting Up an AWS Account

Free tier is sufficient for exercises in this course

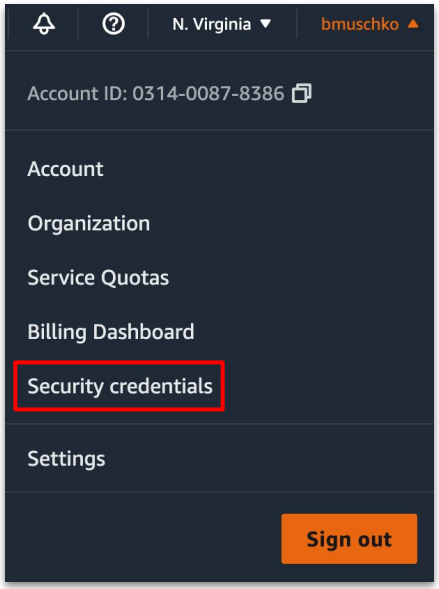


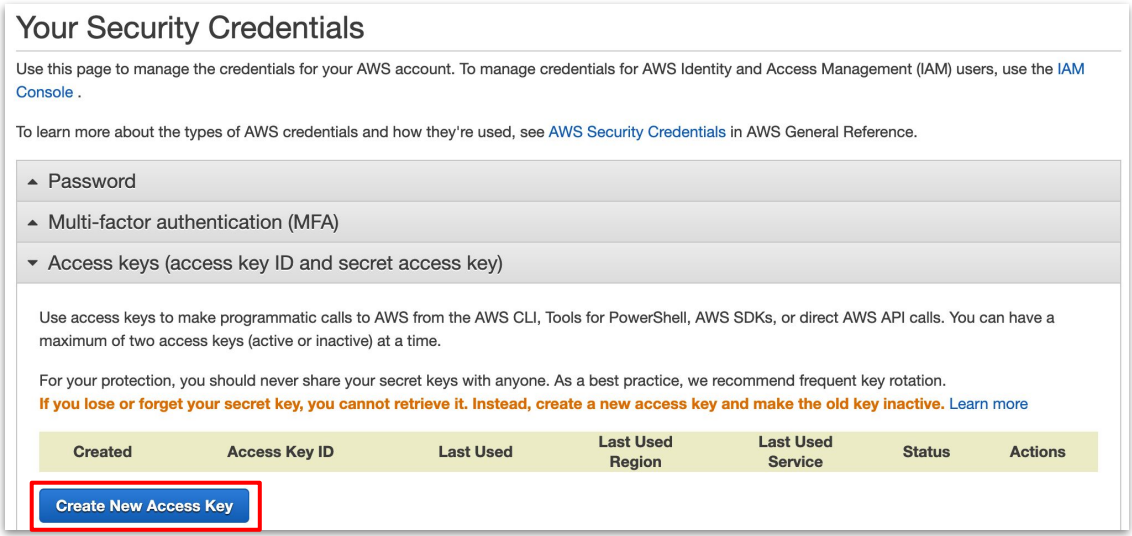




Retrieving AWS Credentials

Create a new access key and store in safe place





Setting Provider Credentials

In current shell or from typical credentials location

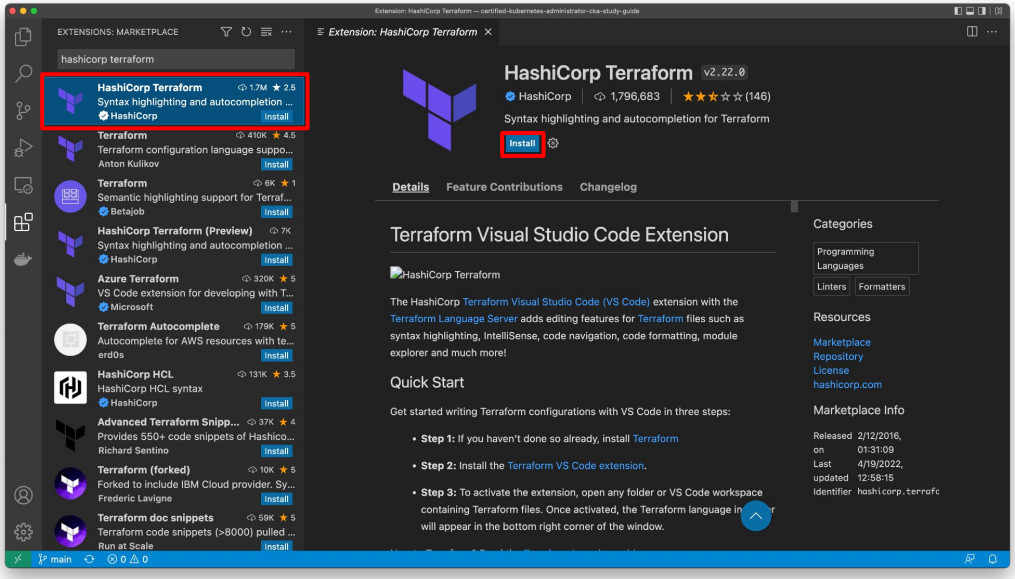
```
$ export AWS_ACCESS_KEY_ID=<access-key-id>
$ export AWS_SECRET_ACCESS_KEY=<secret-access-key>
```

or

```
$ cat $HOME/.aws/credentials
[default]
aws_access_key_id=<access-key-id>
aws_secret_access_key=<secret-access-key>
```

IDE Integration with VSCode

Search for “HashiCorp Terraform” in the Extensions



EXERCISE

Installing Terraform and Setting AWS Credentials

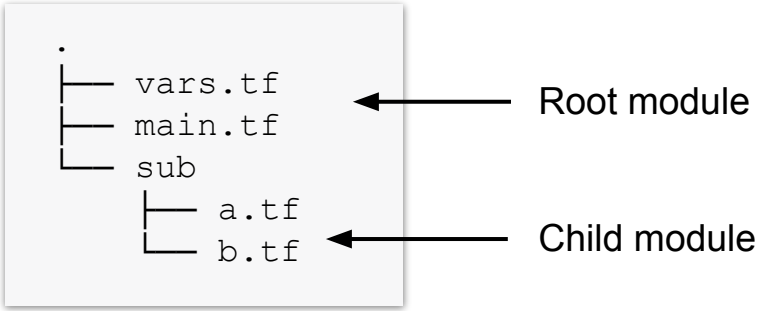
Getting Started With Terraform

Basic Concepts, Syntax, and Workflow

Files and Directories

Terraform configuration is defined by a collection of files

- *Configuration files* contain plain text instruction and have the extension `.tf` or `.tf.json`
- A *module* defines a set of (potentially versioned) configuration file(s)



Object Types

High-level elements used in a configuration file

- *Provider:* Allows Terraform to interact with a cloud provider through its API e.g. AWS or Azure, SaaS provider, or other APIs
- *Resource:* Defines the infrastructure pieces to be created in a target environment e.g. EC2 instance, a VPC, or a web server
- *Data source:* Can query information from a provider that can be used in the configuration e.g. a list of available AMIs

Configuration Syntax

HCL is preferred over JSON

```
<BLOCK TYPE> "<BLOCK LABEL>" "<BLOCK LABEL NAME>" {
  <IDENTIFIER> = <EXPRESSION>
}
```

Block: A container for defining the configuration of an object delimited by curly braces (can have nested blocks)

Argument: A key-value pair defined within a block

Expression: Computed values assigned to an argument

Syntax Constraints

Just of a couple of little gotchas to look out for

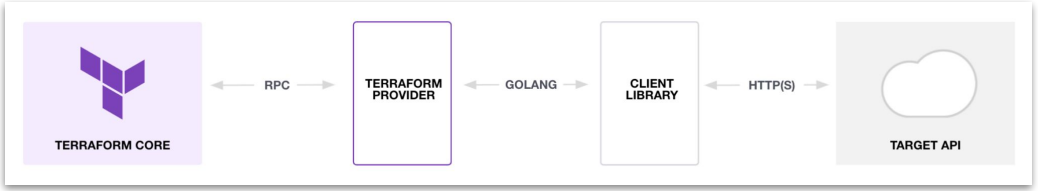
- *Identifiers* can contain letters, digits, underscores (_), and hyphens (-). The first character of an identifier must not be a digit, to avoid ambiguity with literal numbers.
- Comments can be defined by `#`, `//`, or `/* */`.
- Configuration files must always be UTF-8 encoded

Plugin-Based Architecture

Core binary is small, providers are developed as plugins

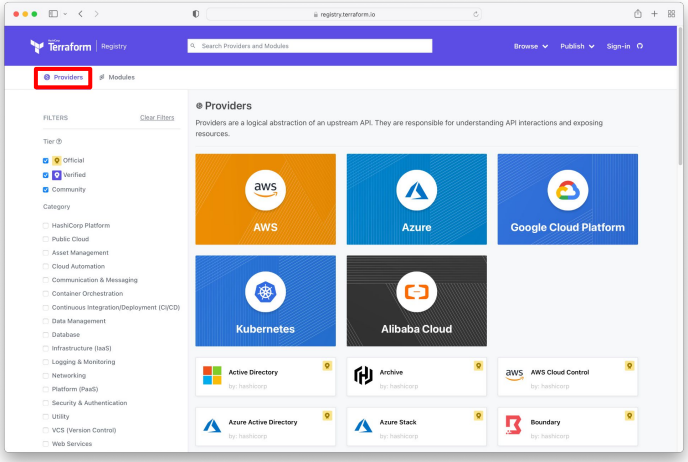
- *Terraform Core:* The binary that communicates with plugins to manage infrastructure resources

- *Terraform plugins:* Executable binaries written in Go that communicate with Terraform core over an RPC interface



Exploring the Provider Registry

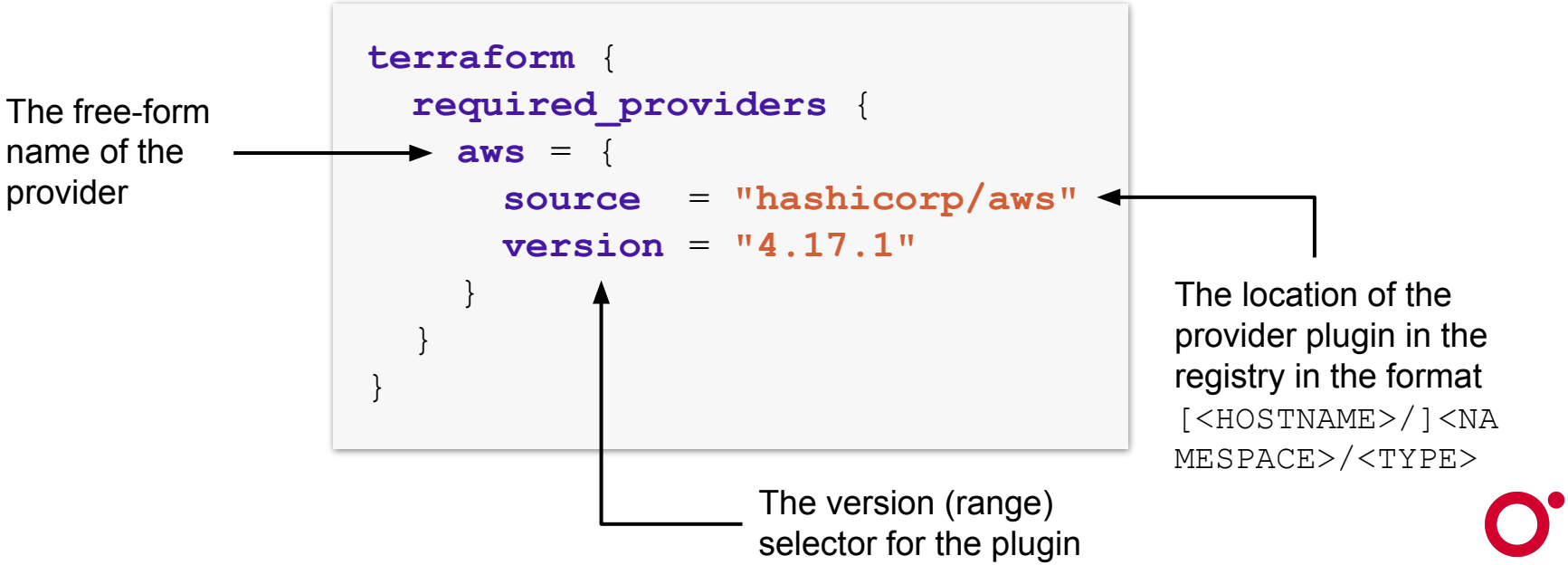
Central location for provider plugins and their documentation



https://registry.terraform.io/browse/providers

Defining Required Provider(s)

Sets up the properties for all providers of the assigned name



Version Constraint & Selection

You can define a concrete version or a version range

Version Value	Meaning
no assigned value attribute	Picks the latest version of the provider available in registry
`>= 1.2.1`	Great than or equal to the version `1.2.1`
`<= 1.2.1`	Less than or equal to the version `1.2.1`
`~> 1.2.1`	Any version in the `1.2.x` range up to the next minor version (`1.3.0`)
`>= 1.2.1, <= 1.5.0`	Any version between `1.2.1` and `1.5.0`

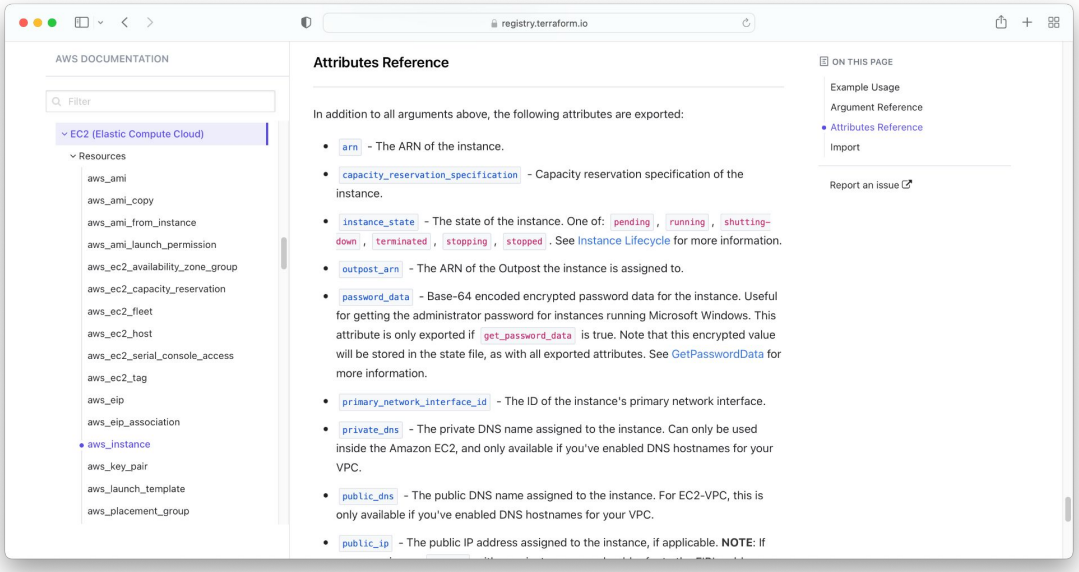
Dependency Lock File

Stores resolved versions + checksum for provider plugins (docs)

- Terraform creates or updates the dependency lock file each time you run the `init` command.
- The lock file is always named `.terraform.lock.hcl` and is meant to be checked into version control.
- Use the `-upgrade` flag with the `init` command to upgrade a provider plugin version.

Provider Documentation

A provider publishes the API (e.g. available attributes) on registry



Configuring Provider(s)

Need to be defined in the root module configuration file

```
provider "aws" {
  region = "us-east-2"
}
```

Default provider: Any resource that does not assign a provider explicitly will use this provider

```
provider "aws" {
  alias = "west"
  region = "us-west-2"
}
```

Aliased provider: A resource can refer to this provider explicitly by assigning the `provider` argument (in this case `aws.west`)

Local Plugin Cache

Core binary is small, providers are developed as plugins

- Terraform automatically fetches plugins from the registry and stores them in the `.terraform` subdirectory
- Caching is enabled by default and a plugin version already available in the `.terraform` subdirectory will be reused
- Cache directory be configured with the environment variable `TF_PLUGIN_DIR` or the CLI option `--plugin-dir`

Configuring Provider Credentials

Provider exposes attributes for consuming credentials

```
provider "aws" {
  region = "us-east-2"
  access_key = "my-access-key"
  secret_key = "my-secret-key"
}
```

Do you not use this way to provide credentials!
The state file with store credentials in plain text.

```
provider "aws" {
  region = "us-east-2"
  shared_credentials_files = ["path-to-credentials-file"]
  profile = "profile-name"
}
```

Defining Resource(s)

Virtual server in AWS aka EC2 instance

```
resource "aws_instance" "web_server" {
  ami           = "ami-0c55b159cbfafe1f0"
  instance_type = "t2.micro"
}
```

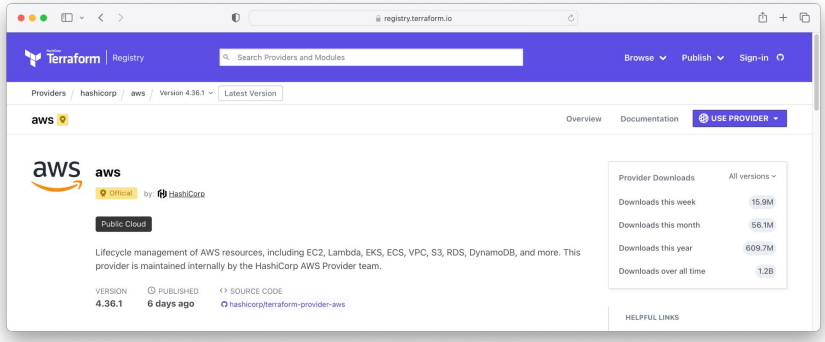
The free or paid Amazon Machine Image (AMI) to run on EC2 instance available via the AWS Marketplace

Type of EC2 instance which provides a certain amount of CPU, memory, disk space, and network capabilities

Provider is Derived from Resource

Defining a provider is optional, Terraform tries to anticipate

```
resource "aws_instance" "web_server" { }
```



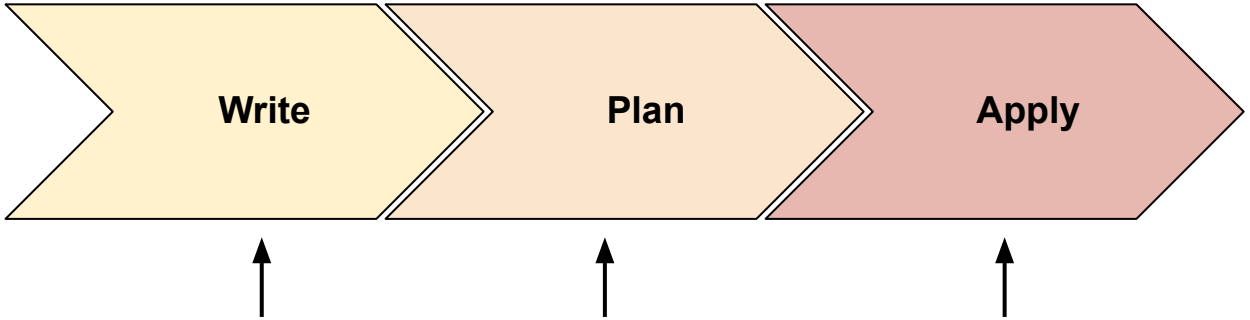
Use the prefix to determine provider on Terraform Registry and download latest version available

EXERCISE

Implementing a
Simple
Configuration File

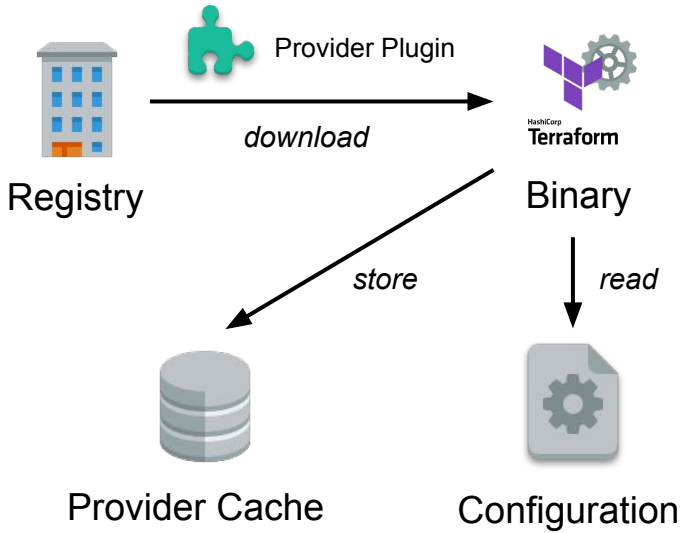
Terraform Core Workflow

Three-step approach on a high-level



Initialize Working Directory

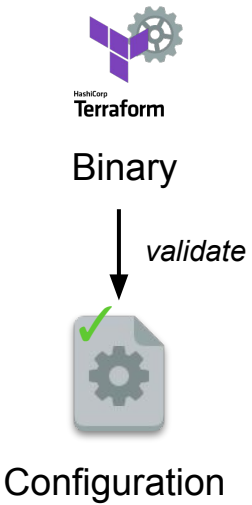
Prepare working directory, parse config, retrieve provider plugins




```
$ terraform init
```

Validate Configuration

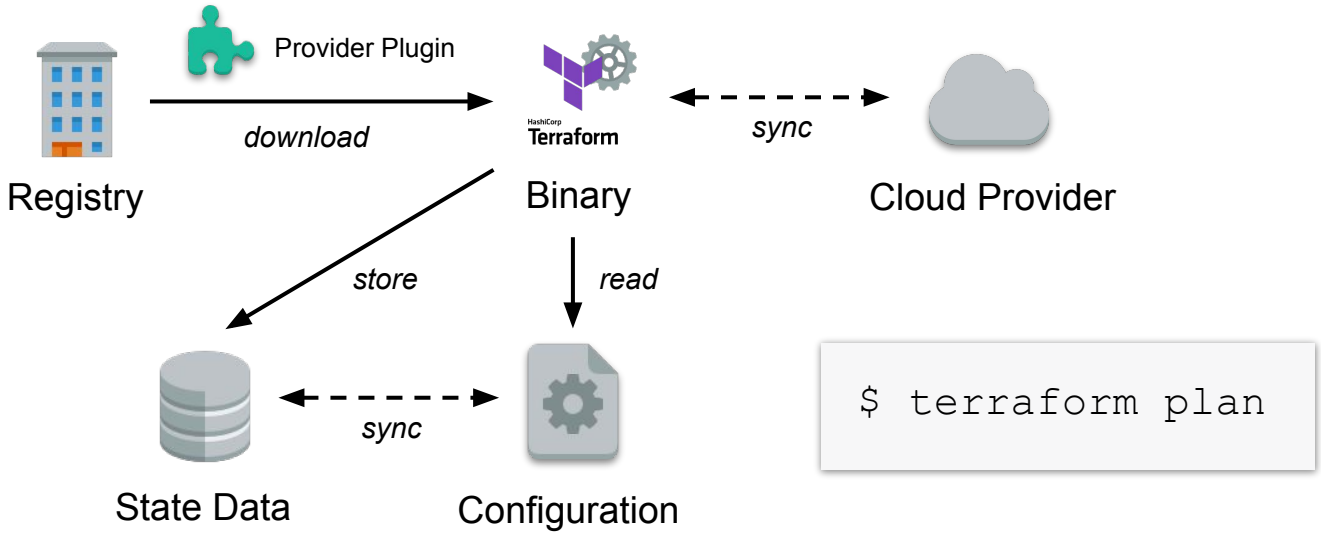
Check for syntax errors, doesn't guarantee successful deployment




```
$ terraform validate
```

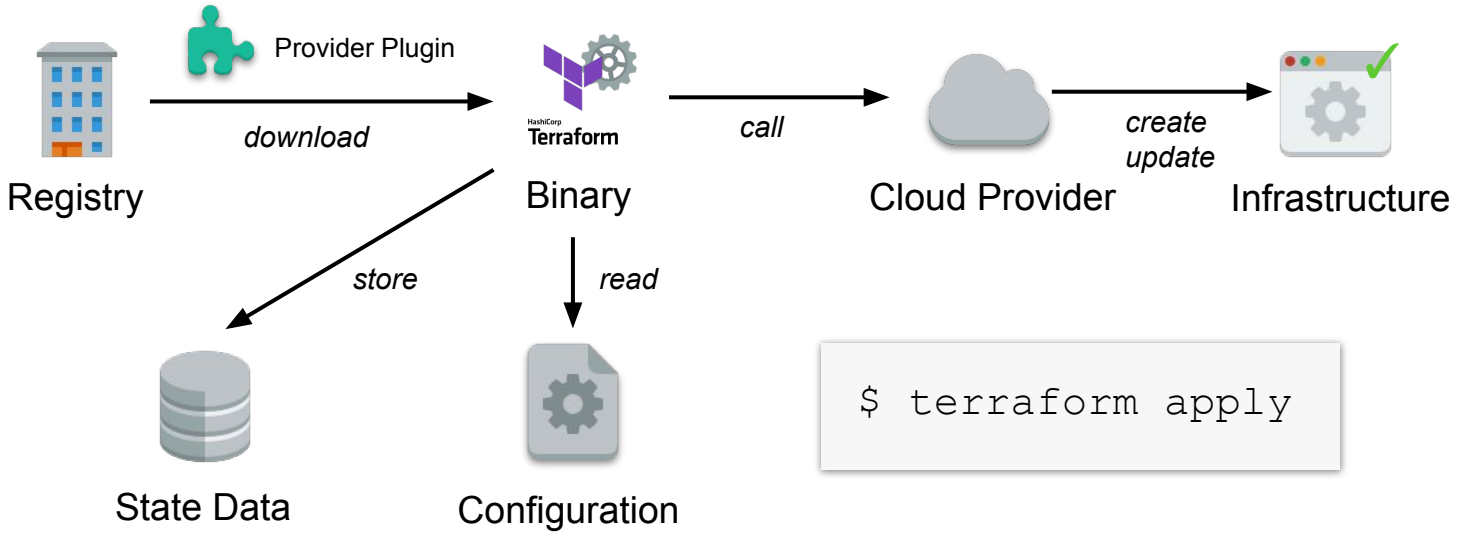
Plan Changes

Determine differences between local state and deployed infra



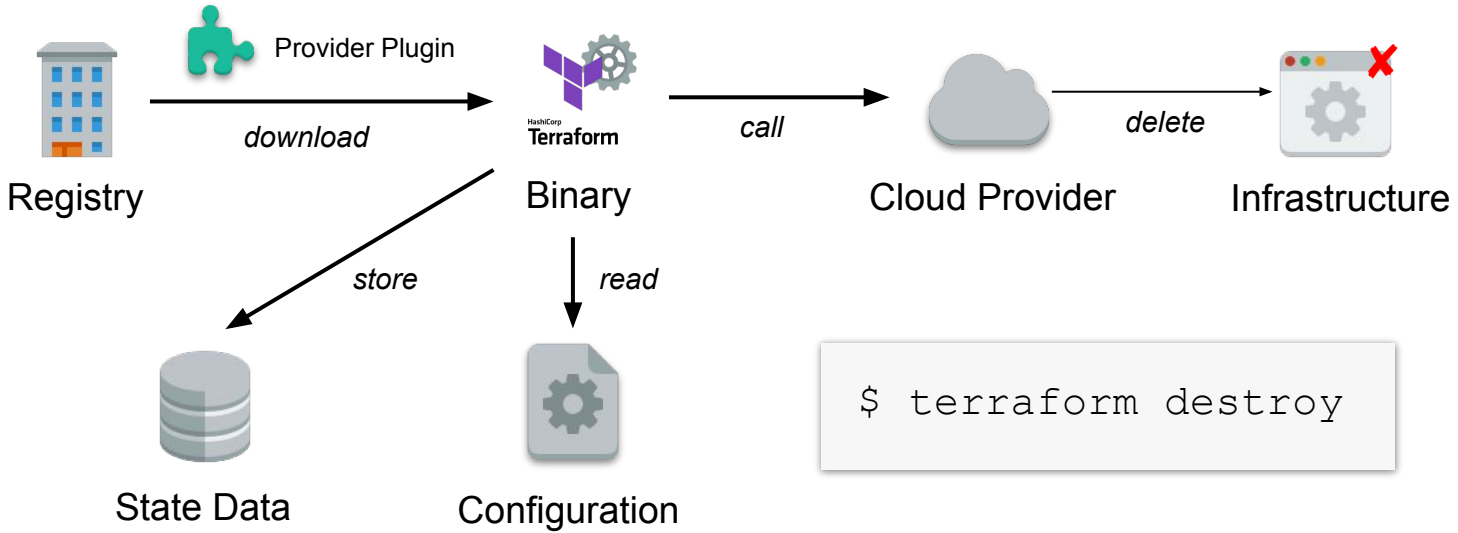
Apply Changes

Deploying the infrastructure or changing its delta



Destroy Infrastructure

Delete infrastructure in target environment based on state data



EXERCISE

Exercising the Core
Terraform Workflow

Q & A

Input Variables, Local/Output Values, and Data Sources

Data Types, Resource Addressing, Variables/Values, Implicit/Explicit Dependencies

Data Types

A value follows one of the data types below

- Primitive
  - `string`
  - `number`
  - `bool`

- Collection or Complex
  - `list/tuple`
  - `set`
  - `map/object`

Primitive Data Types

Definition very similar to programming/scripting languages

```
# string
"hello" or "this is an example"

# number
25 or 4.632

# bool
true or false
```

Collection Data Type Examples

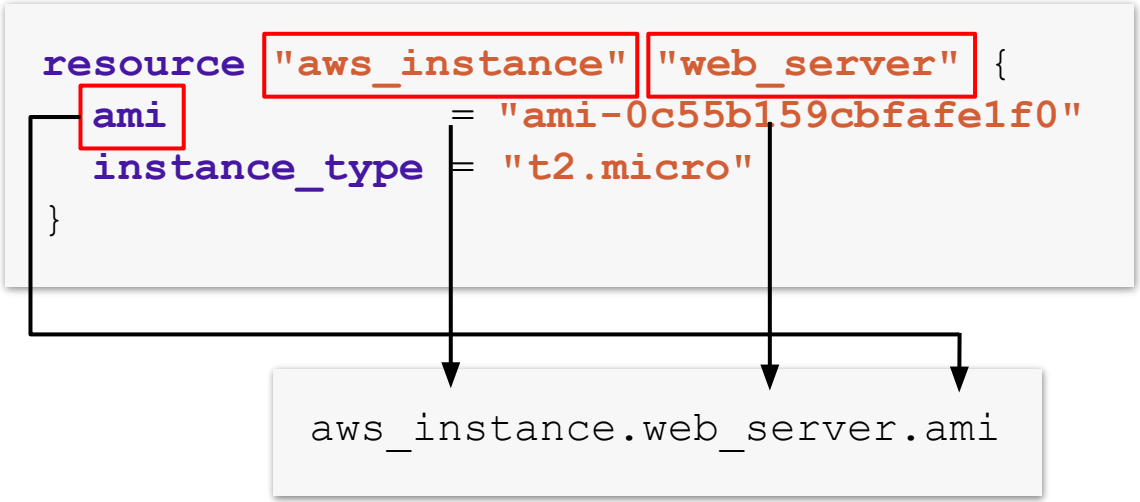
Items in collection can be defined on individual lines for readability

```
# list (or tuple)
["us-west-1a", "us-west-1c"]

# map (or object)
{name = "Mabel", age = 52}
```

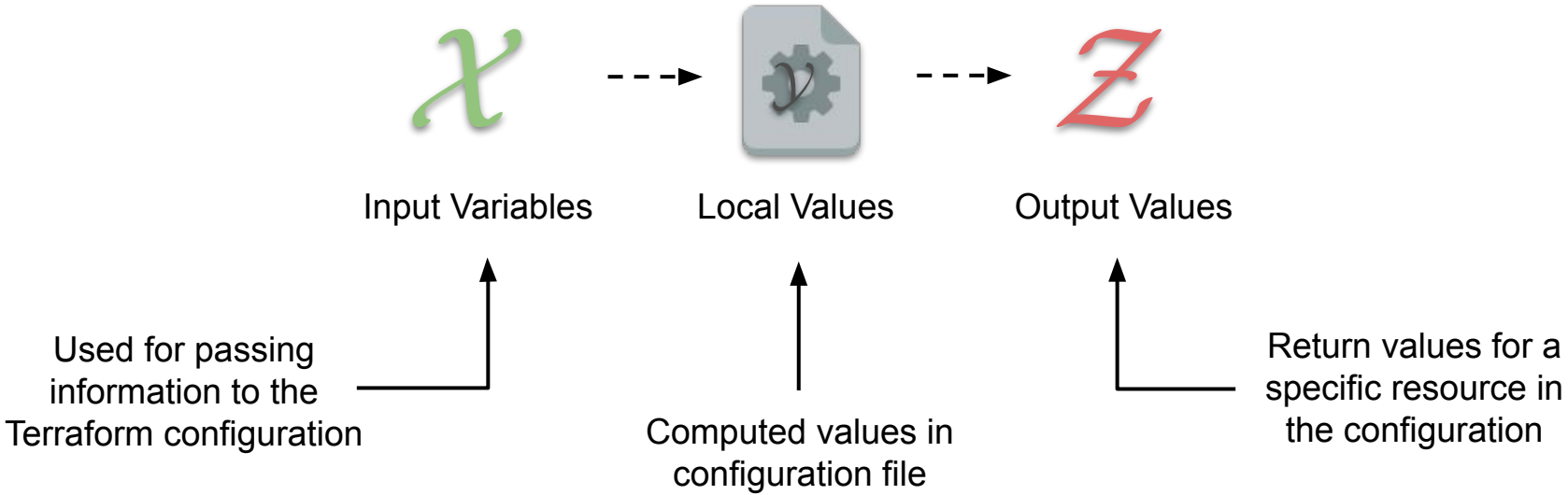
Resource Addressing

Referencing a variable or resource attribute in a different context



Defining Named Values

Concepts for requesting, referencing, and publishing values



Use Cases for Named Values

Understanding when to use which type

Input Variables

---►

“I want to capture values from the CLI when the end user invokes Terraform and use it in my configuration.”

Local Values

---►

“I want to create a variable, assign a value, and reuse it in my configuration similar to a constant.”

Output Values

---►

“I want to render a runtime value in the console output or use it as an input for a resource or module.”

File Naming Conventions

Terraform will automatically resolve those files, but not enforce

Input Variables

`variables.tf`

Local Values

`locals.tf`

Output Values

`outputs.tf`

Defining Input Variables

Configuration file can define 0 to many variables

```
variable "ami_id" {
  type = string
  description = "The AMI identifier to use
                 for EC2 instance."
}

variable "availability_zone_names" {
  type    = list(string)
  default = ["us-west-2"]
}
```

Input Variable Arguments

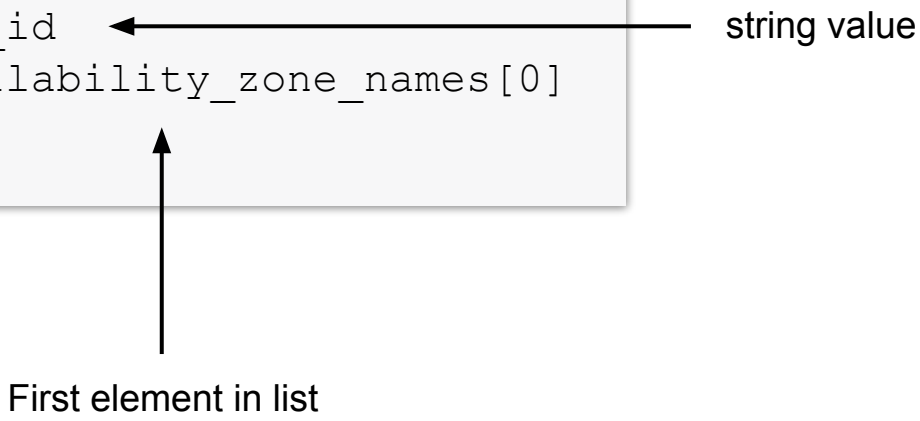
All arguments are optional

Argument	Description
`default`	Value to be used if not provided
`type`	Accepted type for values assigned to variable
`description`	End user description that explains purpose and kind of value
`validation`	Validation rules applied to provided value
`sensitive`	Obfuscates sensitive information in CLI output
`nullable`	Defines if assigned value can be `null`

Referencing Input Variable Values

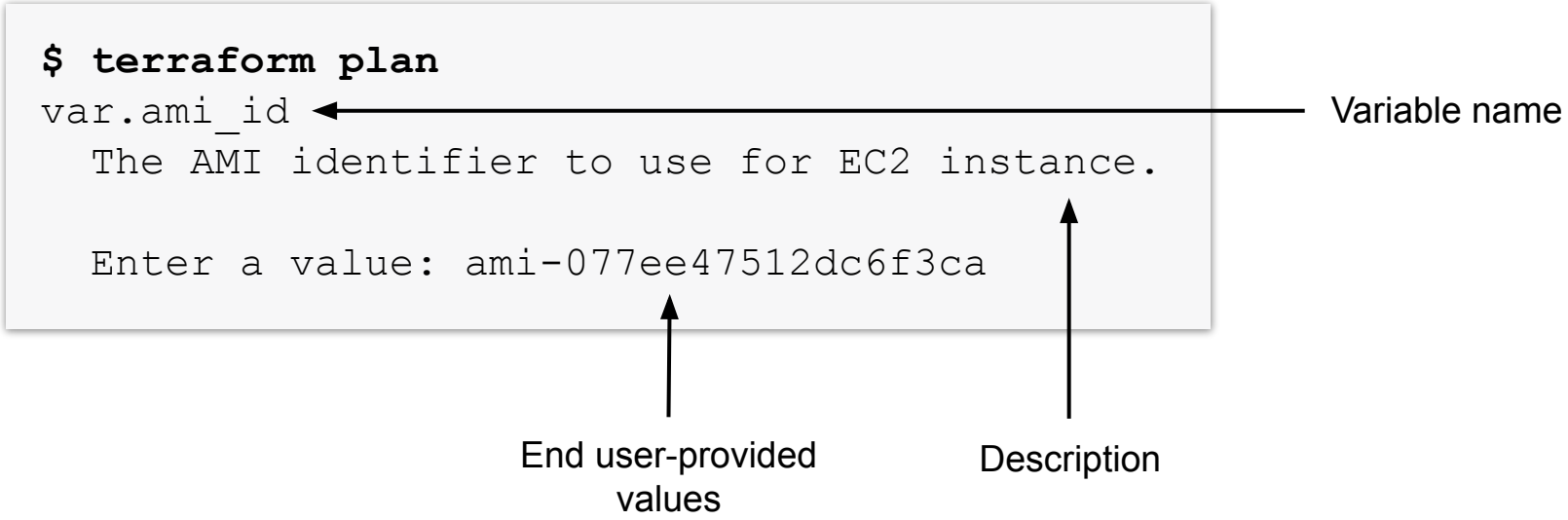
A variable can be used with the `var.name` notation

```
resource "aws_instance" "example" {
  ami           = var.ami_id
  instance_type = var.availability_zone_names[0]
}
```



Requesting Variable Input Values

End user has to provide value if no default value has been set



Variable Input Values from CLI

`-var` option when running the `plan` and `apply` commands

```
$ terraform apply -var="ami_id=ami-0c55b159cbfafe1f0"
...
$ terraform apply
  -var='availability_zone_names=["us-east-1a", "us-west-1c"]'
...
```

Variable Input Values from Files

`-var-file` option can point to a file containing input variables

```
$ terraform apply -var-file="runtime-var.tfvars"
```

```
ami_id = "ami-0c55b159cbfafe1f0"
availability_zone_names = [
  "us-east-1a",
  "us-west-1c"
]
```

runtime-var.tfvars

Auto-Loading of Variable Files

Standard naming convention will apply

- Files named exactly `terraform.tfvars` or `terraform.tfvars.json`
- Any files with names ending in `.auto.tfvars` or `.auto.tfvars.json`

Injecting Secrets as Inputs

Input variables will be stored in the state in plain text

```
$ export TF_VAR_third_party_pwd=s3cr3t
$ export TF_VAR_api_key=a8an23sdf023xmkdd
```

main.tf

```
# use variables
var.third_party_pwd
var.api_key
```

Validating Input Variables

Built-in functions can be used to implement validation logic

```
variable "ami_id" {
  ...
  validation {
    condition = length(var.ami_id) > 4 &&
                substr(var.ami_id, 0, 4) == "ami-"
    error_message = "The image_id value must be a valid
                     AMI id, starting with \"ami-\"."
  }
}
```

EXERCISE

Input Variable Definition and Consumption

Defining Local Values

Supports reusability of the same value in a configuration

```
locals {
  some_other = var.from_cli
  default_tags = {
    Organization = "O'Reilly"
    Owner = "Benjamin Muschko"
  }
}
```

Parsed value from input variable

Referencing Local Values

A local value can be used with the `local.name` notation

```
provider "aws" {
  region = "us-east-2"
  default_tags {
    tags = local.default_tags
  }
}
```


Assigns the local value from the locals definition block

EXERCISE

Local Value
Definition and
Consumption

Defining Output Values

Make information about infrastructure available on CLI

```
output "example_ip_address" {
  value = aws_instance.example.private_ip
  description = "The private IP address of the
                 main server instance."
}
```

References the private IP address attribute of the AWS instance named `example`

Output Values in CLI

Outputs can be queried from the state database (if populated)

```
$ terraform output
╷
│ Warning: No outputs found
│
│ The state file either has no outputs defined, or all the
│ defined outputs are empty.

$ terraform apply
example_ip_address = "..."

$ terraform output
example_ip_address = "..."
```

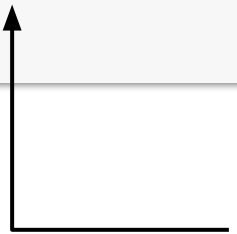
EXERCISE

Output Value Definition and Rendering

Implicit Dependencies

Using an output value as input for a resource

```
resource "aws_eip" "ip" {
  vpc = true
  instance = aws_instance.example.id
}
```

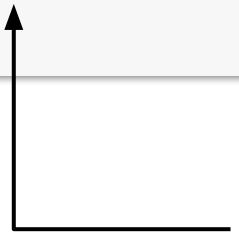


Ensures that EC2 instance is created before the elastic IP resource

Explicit Dependencies

Sometimes Terraform cannot determine dependencies

```
module "example_sqs_queue" {
  source = "terraform-aws-modules/sqs/aws"
  version = "2.1.0"
  depends_on = [aws_s3_bucket.example, aws_instance.example_c]
}
```



Declaration order does not guarantee execution order

Defining Data Sources

Get information about resources external to Terraform


```
# define data source
data "github_repository_pull_requests" "pull_requests" {
  base_repository = "example-repository"
  base_ref = "main"
  state = "open"
}

# Reference data
data.github_repository_pull_requests.pull_requests.results
```

EXERCISE

Defining and Consuming a Data Source

Q & A

Iteration Control, Functions, and Expressions

Loops, Dynamic Blocks, Built-In Expressions

Looping Constructs

Terraform provides looping syntax for different use cases

- `count` argument: Assigns an integer that determines # of loops
- `for_each` argument: Iterates over each element of a `map` or `set`
- `for` expression: Used to transform elements in a `map` or `set`
- `dynamic` blocks: Similar to a traditional for-loop but uses the `dynamic` nested block syntax

Count Argument

Count is a simple integer value assignment

```
resource "aws_instance" "app_server" {
  count = 3
  ami = "ami-0c55b159cbfafe1f0"
  instance_type = "t2.micro"
  tags {
    Name = "app_server_${count.index}"
  }
}
```

Current index of loop
can used as variable

For Each Argument

Iteration element can be referenced by `key` and `value` attribute

```
resource "azurerm_resource_group" "rg" {
  for_each = {
    a_group = "eastus"
    another_group = "westus2"
  }
  name     = each.key
  location = each.value
}
```

`map` data type with 2 entries

For a `set` data type the `key` is the same as `value`

For Expression

Applies an expression to each element to transform it

```
output "all_tags" {
  value = [for key, value in var.tags :
           upper(key) => upper(value)]
}
```

Iterate over elements in a `map`

Transforms key and value with function and outputs a `map`

Dynamic Block

Helps with implementing DRY for more elaborate configurations

```
resource "aws_security_group" "security" {
  ...
  dynamic "ingress" {
    for_each = local.ingress_rules

    content {
      description = ingress.value.description
      from_port   = ingress.value.port
      to_port     = ingress.value.port
      protocol    = "tcp"
      cidr_blocks = ["0.0.0.0/0"]
    }
  }
}
```

Local variable pointing to a `set` of tuples with port numbers and descriptions

Configure the whole “block” for each iteration the `set`

EXERCISE

Declaring a Loop Sourced from an Input Variable

Built-In Functions

Functionality for transforming, combining, and formatting data

- Grouped into higher-level categories e.g. collections, type conversion, date and time (docs)
- Syntax in code: `function_name(argument, ...)`
- Functions can be combined with each other by nesting them
- Terraform provides a console to try out functions against state data

Function Examples

Available functions are vast, suitable for most common use cases

```
# return largest value in a set
max([22, 5, 99])
> 99

# base64-encode a string value
base64encode("Hello World")
> SGVsbG8gV29ybGQK

# extract a substring from a given string
substr("hello world", 1, 4)
> ello
```

Terraform Console

Test functions against the current state data (and locks it)

```
$ terraform console
> var.instance_count
3
> range(0, var.instance_count)
tolist([
  0,
  1,
  2,
])
```

Get the value of the input variable `instance_count`

Execute the `range` function against the variable

EXERCISE

Using Built-In Functions to Transform Data

Interacting with Modules

Module Structure and Syntax, Inputs & Outputs

What is a Module?

Reusable functionality in the world of Terraform

- Usually defines inputs, resources/data sources, and outputs (though they are all optional)
- Modules are versioned (standardized on semantic versioning)
- The `init` command will download remote modules and store them in the `.terraform` directory

Module Sources

A module can be sourced from different locations

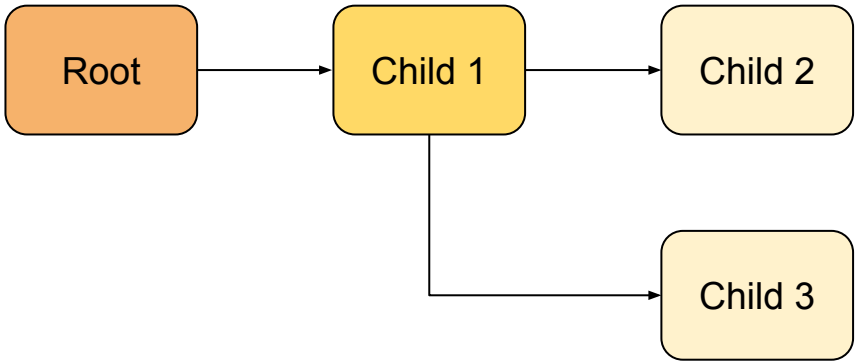
- A local path to a directory present on disk
- A registry like the Terraform registry
- A Git repository e.g. GitHub or BitBucket
- A HTTP(S) URL that follows a provider protocol

Root and Child Modules

Modules can be consumed on any level of the hierarchy

main.tf

```
module "child-1" {
  ...
}
```



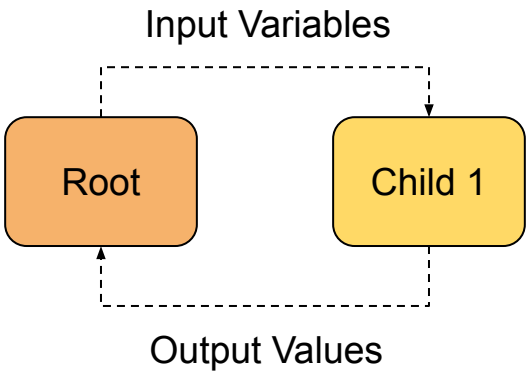
child-1/main.tf

```
module "child-2" {
  ...
}

module "child-3" {
  ...
}
```

Module Data Exchange

Modules only communicate via inputs and outputs



Module Example

Organized in a subdirectory, and defined by `.tf` files

modules/eks/main.tf

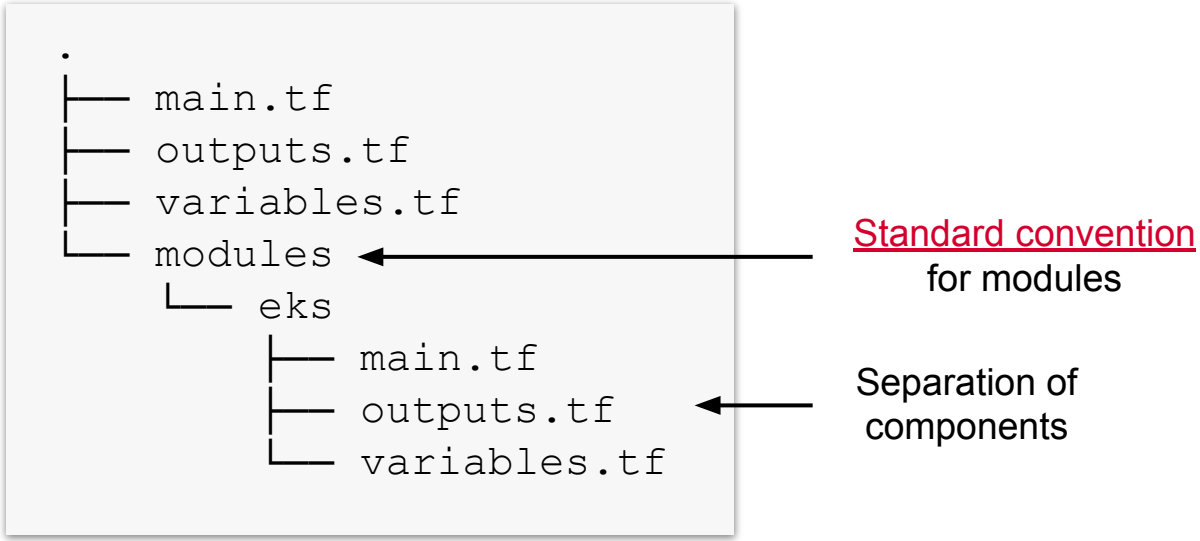
```
variable "cluster_name" {
  type = string
}

resource "aws_eks_cluster" "eks_example" {
  name = "${var.cluster_name}-eks"
  ...
}

output "endpoint" {
  value = aws_eks_cluster.eks_example.endpoint
}
```

Module Structure

Organized in a subdirectory, and defined by `.tf` files



Consuming a Local Module

References by `source`, no version needs to be defined

main.tf

```
module "aws_eks_cluster" {
  source = "./modules/eks"
  cluster_name = "my_cluster"
}

resource "..." {
  endpoint =
module.aws_eks_cluster.endpoint
}
```

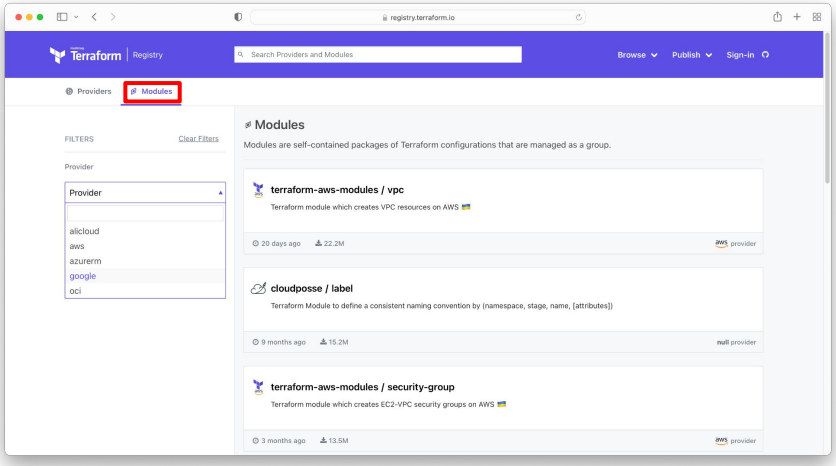
Location of module in directory structure

Providing the value for the input variable

Accessing the output value from local module

Exploring the Module Registry

Similar to providers, modules are available Terraform registry



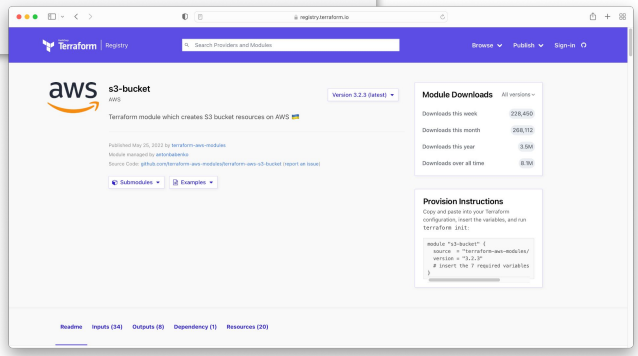
https://registry.terraform.io/browse/modules

Consuming a Public Module

Define `source` *and* `version`

```
module "s3-bucket" {
  source = "terraform-aws-modules/s3-bucket/aws"
  version = "3.2.3"
}
```

Follows the same conventions and notation as provider versions



EXERCISE

Implementing and Using a Custom Module

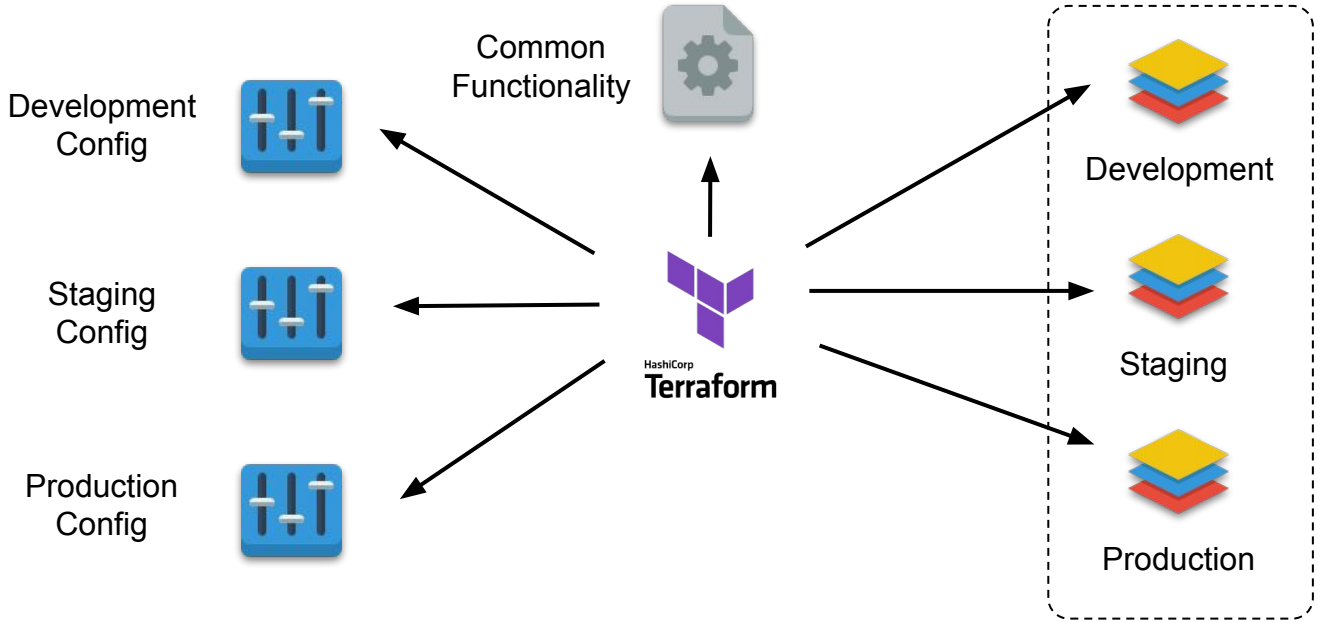
Q & A

Managing Multiple Runtime Environments

Workspaces, Commands, Variable Values, Separated State

Multiple Environments

Commonalities and differences



Handling Environments

A workspace manages requirements

- Shared configuration, different input variable values per context
- Unique credentials per environment to decrease security risks
- Holding unique state per environment
- Increased maintenance effort and potential complexity to end users
- HashiCorp discourages use of workspaces and offers alternatives

The Default Workspace

Cannot be deleted and uses state file in root directory

```
$ terraform workspace show
default

$ terraform workspace list
* default
```

```
.
└── terraform.tfstate
```

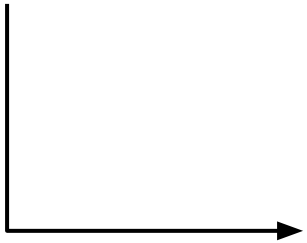
Marks the selected workspace with an asterisk character

Creating a New Workspace

Built-in command that creates a dedicated state folder

```
$ terraform workspace new development
Created and switched to workspace "development"!
```

Every workspace has its own folder



```
.
└── terraform.tfstate.d
    └── development
```

Workspace Variable Values

Per-workspace configuration needs to be resolvable

Development

Variable	Value
instance_type	t2.nano
instance_count	1

Staging

Variable	Value
instance_type	t2.micro
instance_count	2

Production

Variable	Value
instance_type	t2.small
instance_count	4

Defining a Workspace Value

Specify a variable of type `map` in `locals.tf` file

```
locals {
  ec2_instance_type = {
    development = "t2.nano"
    staging = "t2.micro"
    production = "t2.small"
  }

  ec2_instance_count = {
    ...
  }
}
```

Assign key-value pairs per environment

Repeat for every workspace-specific variable

Resolving a Workspace Value

Use the variable `terraform.workspace` to select value

```
resource "aws_instance" "web_server" {
  ami = "ami-0c55b159cbfafe1f0"
  instance_type = local.ec2_instance_type[terraform.workspace]
  instance_count = local.ec2_instance_count[terraform.workspace]
}
```

Selects value in corresponding `map` variable

Switching Between Workspaces

Use `select` command to target a different environment

```
$ terraform workspace list
  default
  development
* production
  staging

$ terraform workspace select staging
Switched to workspace "staging".

$ terraform workspace show
staging
```

Deleting a Workspace

Select different workspace first, then run `delete` command

```
$ terraform workspace select development
Switched to workspace "development".

$ terraform workspace delete staging
Deleted workspace "staging"!
```

Removes workspace folder + state file

```
.
└── terraform.tfstate.d
    ├── development
    └── production
```

EXERCISE

Managing Multiple Environments With Workspaces

Implementing and Maintaining State

Local vs. Remote Backend, State Locking, Secret Management

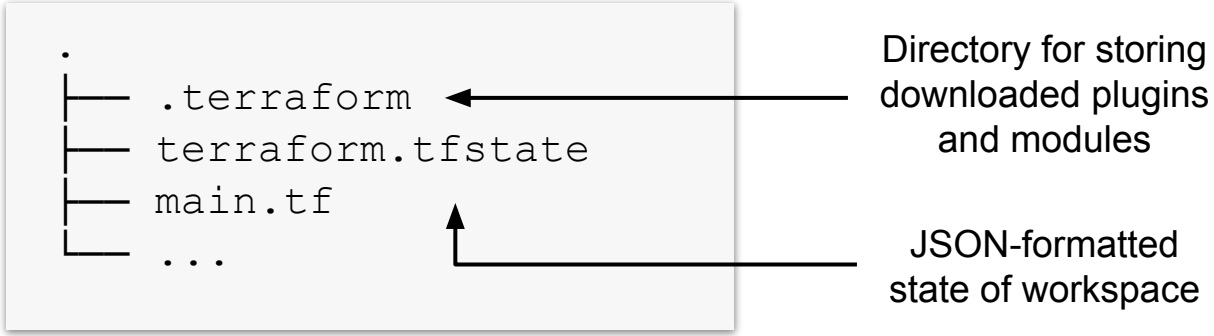
Holding State

Allows for comparing desired with current infrastructure definition

- Terraform only creates/updates what has actually changed
- Enabler for improving performance
- The commands `plan` and `apply` interact with the state
- Local or remote backend for different use cases

The Default Local Backend

Stored in the `terraform.tfstate` file in workspace directory



Configuring the Local Backend

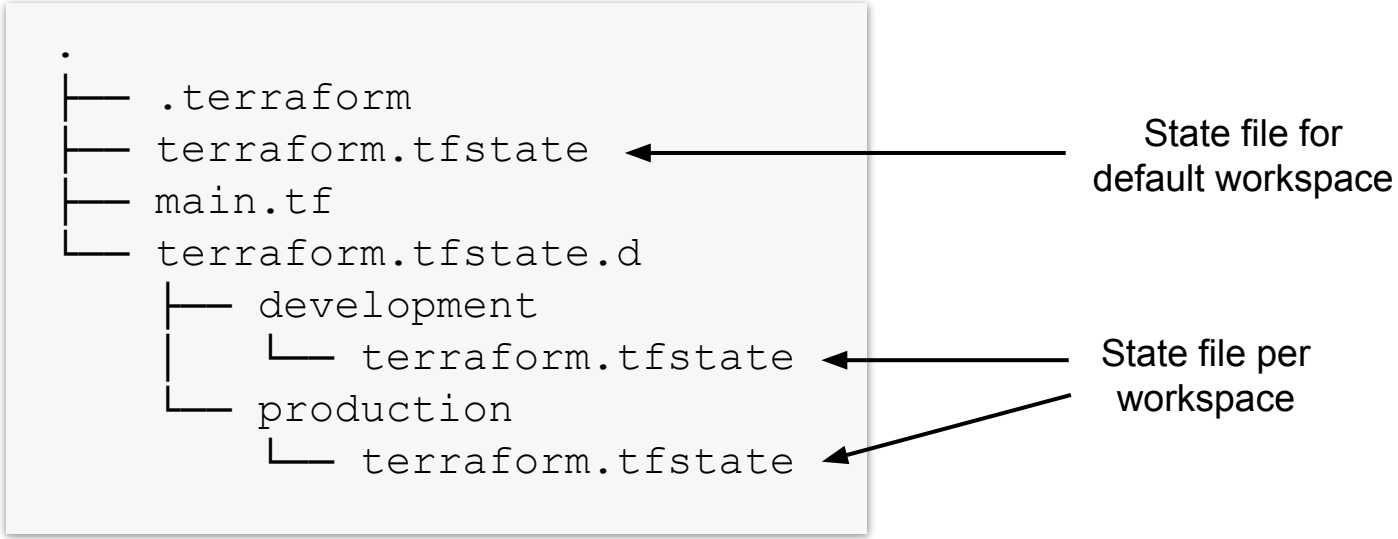
Default file & location can be changed by CLI or configuration

```
terraform {
  backend "local" {
    path = "relative/path/to/terraform.tfstate"
  }
}
```

For ad-hoc tasks, you can use the `-state` command line option

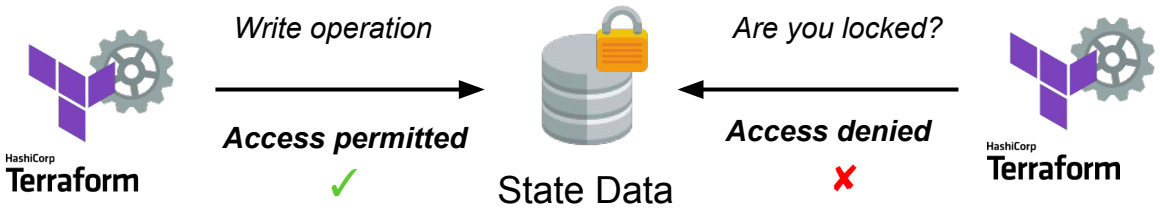
Local State File Per Workspace

State per environment is separated by subdirectory



State Locking

Ensures that state does not corrupted by concurrent access



Lock management can be circumvented using the `-lock=false`.

Caution!

Remote Backends

Optimized for access by multiple users

- Never stores state data on local disk, only loaded into memory and flushed after the operation
- Locking is established on remote backend implementation
- Terraform currently supports different backend implementations
- Enhanced backends (e.g. Terraform Cloud and Enterprise) run Terraform operation on remote service

Remote Backend Authentication

Credentials shouldn't be configured in `.tf` file

```
terraform {
  backend "remote" {
    hostname = "app.terraform.io"
    organization = "company"

    workspaces {
      name = "my-app-prod"
    }
  }
}
```

Credentials should be provided as environment variables to avoid sending them as plain text over the wire or committing them to version control

Partial Backend Configuration

Information can be provided from the CLI with `init` command

```
terraform {
  backend "remote" {
    hostname = "app.terraform.io"
    organization = "company"

    workspaces {
      name = "my-app-prod"
    }
  }
}
```

```
$ terraform init
-backend-config=organ
ization=company
```

Terraform Cloud Configuration

Using Cloud require a specific notation (docs)

```
terraform {
  cloud {
    organization = "automated-ascent"
    hostname = "app.terraform.io"

    workspaces {
      tags = ["my-app-prod"]
    }
  }
}
```

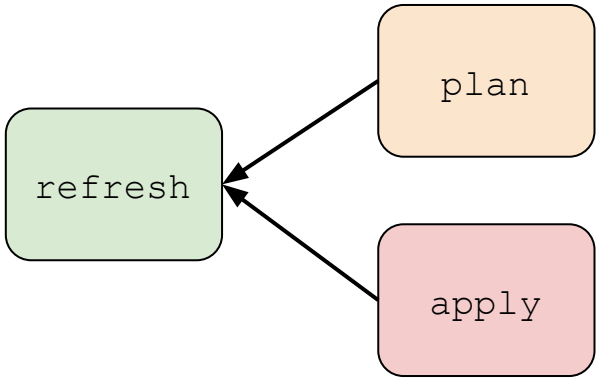
Secret Management & State

State data is not encrypted and shouldn't store sensitive data

- Sensitive data can be provided with environment variables for some remote backend implementations
- Enhanced backends send and store state information in encrypted form
- Credential-management platforms like HashiCorp Vault can integrated as a viable alternative for storing and providing credentials

Managing Resource Drift

Ensures that state synchronizes with deployed infrastructure




```
$ terraform refresh
```

No need to call explicitly

The `plan` and `apply` command automatically refresh the state.

Example Refresh Output

Calculated differences between state and cloud are rendered

```
$ terraform plan
Refreshing Terraform state in-memory prior to plan...
The refreshed state will be used to calculate this plan, but will not be
persisted to local or remote state storage.

aws_instance.example: Refreshing state... (ID: i-011a9893eff09ede1)

------------------------------------------------------------------------

An execution plan has been generated and is shown below.
Resource actions are indicated with the following symbols:
  ~ update in-place

Terraform will perform the following actions:

  ~ aws_instance.example
      tags.drift_example: "v2" => "v1"
```

Output will list actions when `apply` command is performed

Resource Drift Output Symbols

Refresh output shoulds differences and their actions up `apply`

Symbol	Meaning
+	Create
–	Destroy
-/+	Replace (destroy and then create, or vice-versa if create-before-destroy is used)
~	Update in-place
<=	Read (only applies to data sources)

Deprecation of `refresh` Command

The command will be removed in a future Terraform version

- The `refresh` command means the same `apply -refresh-only -auto-approve`. Therefore, the state will be overwritten. You do have a backup file with the file extension `.backup`.

- Invalid provider credentials or wrong credentials for a region can lead to an incorrect state.

- It's recommended to run `plan`/`apply` with `-refresh-only` option. The `apply` explicitly asks for confirmation before overwriting the state file. More information on this blog post.

EXERCISE

Managing Resource Drift

Advanced Terraform Workflows

`fmt`, `validate`, `import`, `state`, Enabling verbose logging

Validating Configuration Files

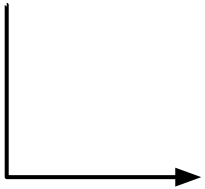
Check for syntactical errors in configuration files of a directory

- Functionality provided by the `validate` command
- Does not consider provided variables or state
- Does not make a guarantee on successful deployment
- Should be run before `plan`/`apply` commands and is a good fit for CI/CD pipelines

Validation Example

Renders errors on terminal output

```
instance_type = ["t2.micro"]
```



```
$ terraform validate
╷
│ Error: Incorrect attribute value type
│
│   on main.tf line 16, in resource "aws_instance" "app_server":
│   16:   instance_type = ["t2.nano"]
│
│ Inappropriate value for attribute "instance_type": string
required.
```

Formatting Configuration Files

Align configuration with standard style conventions

- Functionality provided by the `fmt` command
- Applies to `.tf` and `.tfvars` files in the current directory, use `-recursive` to apply formatting to all subdirectories
- Other CLI options are available: `-list=false`, `-write=false`, `-diff`, `-check`
- Should be performed before committing to version control

Reformatting Example

Aligns multiple attribute assignments for a resource

```
ami = "ami-0c55b159cbfafe1f0"
instance_type = "t2.micro"
```

```
$ terraform fmt
```

```
ami           = "ami-0c55b159cbfafe1f0"
instance_type = "t2.micro"
```

EXERCISE

Validating and
Formatting
Configuration Files

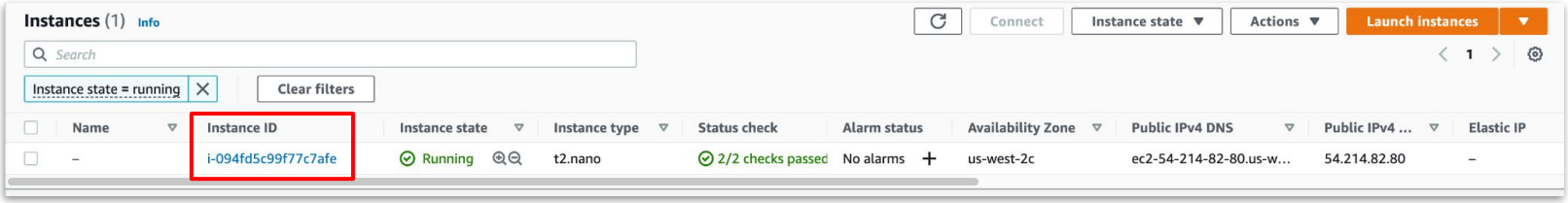
Importing Existing Infrastructure

Bring manually created infrastructure under Terraform's control

- Functionality provided by the `import` command
- Loads supported resources into your Terraform workspace's state
- Does not automatically generate the configuration to manage the infrastructure
- Importing infrastructure is a multi-step process

Identifying the Resource

Every resource to be imported needs to have an identifier



For an EC2 instance, the resource identifier is the *instance ID*

Adding a Resource Config Block

The `import` command will attach state to configuration

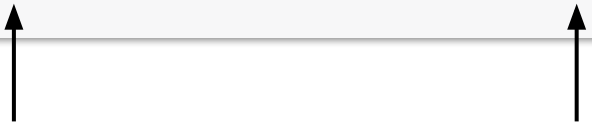
```
resource "aws_instance" "web_server" {}
```

Do not add any specific configuration yet

Running the Import Command

Provide the configuration ID + resource ID

```
$ terraform import aws_instance.web_server i-094fd5c99f77c7afe
```



Check Imported State

Render the resource state that could be imported

```
$ terraform show
```

Manually Add Configuration

Fill in missing information that couldn't be derived

```
resource "aws_instance" "web_server" {
   ...
}
```

Add the configuration of the resource

Plan and Apply Changes

Iteratively plan, add configuration, and finally apply

```
$ terraform plan
$ terraform apply
```

Interacting with Terraform State

Fine-grained interactions with state backend

- Manual updates to the state document, local or remote, should be avoided
- Functionality provided by the `state` command
- Subcommands available for listing resources, removing resources, moving items, pulling/pushing the state between local and remote backend, and rendering the current state

Listing Current Resources

“What resources are currently managed by Terraform?”

```
$ terraform state list
aws_instance.web_server
aws_ebs_volume.web_server_vol
```

See command details

Rendering Resource Attributes

“Show me the current configuration of this resource.”

```
$ terraform state show aws_instance.web_server
resource "aws_instance" "web_server" {
  ...
}
```

See command details

Renaming a Resource

“Renaming a resource without deleting/recreating it first”

```
$ terraform state mv aws_instance.web_server
  aws_instance.app_server
Move "aws_instance.web_server" to "aws_instance.app_server"
Successfully moved 1 object(s).
```

See command details

Remove an Item from the State

“I want to manage a resource outside of Terraform”

```
$ terraform state rm aws_instance.web_server
Removed aws_instance.web_server
Successfully removed 1 resource instance(s).

# Remove the resource from the configuration
$ terraform plan
$ terraform apply
```

See command details

EXERCISE

Interacting with the
State From the CLI

Enabling Verbose Logging

Rendering detailed information in error situations

- Terraform writes logs to standard error and offers the following log levels: `TRACE`, `DEBUG`, `INFO`, `WARN`, and `ERROR`
- The log level can be set via the environment variable `TF_LOG`
- The log level for Terraform itself and provider plugins can be controlled with the environment variable `TF_LOG_CORE` and `TF_LOG_PROVIDER`

Q & A

Understand Terraform Cloud Capabilities

How Does it Help in an Enterprise Setting?

What is Terraform Cloud?

Commercial, cloud-hosted distribution of Terraform

- Enhanced features for team collaboration and enterprise-level infrastructure management (e.g. security and compliance)
- Hosted service available at https://app.terraform.io
- Terraform Enterprise is a self-hosted distribution of Terraform Cloud

Feature: Account Management

Authentication and authorization

- An company can model organizational structure with the concepts *users*, *teams*, and *organizations*
- Permissions can be defined to control authorization of operations
- **Benefit:** Added security by only allowing authenticated access, User can only execute operations with granted permissions, Single Sign On (SSO) integration

Feature: VCS Integration

Terraform workflow integration as part of CI/CD automation

- Supports GitHub, GitLab, BitBucket, and Azure DevOps
- Automatic execution of a Terraform workflow upon commit
- Simplified release process of Terraform modules
- **Benefit:** Simplified setup of automatic execution for typical Terraform workflows against code changes without a lot of manual intervention

Feature: Workspaces

Not to be confused with Terraform OSS workspace

- Terraform Cloud and OSS uses the same terminology, however, the meaning for a *workspace* is different
- In Terraform Cloud a workspace is associated with a VCS repository
- Workspace settings include variable values, state, and secrets, and historical logs
- **Benefit:** Avoid local state file(s) and centralize state on remote

Feature: Config. Compliance

Enforced compliance as part of the plan-apply workflow

- Sentinel and Open Policy Agent (OPA) are compliance frameworks for centralizing company rules as code and enforcing them
- Triggers after `terraform plan` and before `terraform apply` commands and fails command if configuration doesn't follow policies
- **Benefit:** Standardizing on resource naming conventions or validating attribute values

Feature: Private Registry

Added security by only allowing members to access registry

- Enterprises can host their providers and modules in a private registry (only accessible to members of the organization)
- Includes functionality like versioning, and search capabilities like you already know from the public Terraform registry
- **Benefit:** Binaries cannot be modified by malicious attacker, attacker cannot publish a new version of binaries that contains malicious code

Other Notable Features

Refer to the documentation for more information

- API access: Ability to run Terraform operations via a RESTful API
- Remote operations: Consistent and reliable run environment with the help of virtual machines
- Cost estimation: Calculates expected cost when run on cloud provider like AWS, GCP, and Azure

Q & A

EXERCISE

Apache Web Server
on AWS Accessible
via the Internet

Summary & Wrap Up

Last words of advice...

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Thank you