

# Terraform Fundamentals

Allen Sanders  
(Senior Technology Instructor)





# Join Us in Making Learning Technology Easier



## Our mission...

Over 16 years ago, we embarked on a journey to improve the world by making learning technology easy and accessible to everyone.



## ...impacts everyone daily.

And it's working. Today, we're known for delivering customized tech learning programs that drive innovation and transform organizations.

In fact, when you talk on the phone, watch a movie, connect with friends on social media, drive a car, fly on a plane, shop online, and order a latte with your mobile app, you are experiencing the impact of our solutions.

Over The Past Few Decades, We've Provided

Over  
**62,300,000**  
expert-led learning hours

In 2019 Alone, We Provided





# Technologies we cover



Develop  
Intelligence



Jenkins



ANSIBLE



cassandra



docker



GraphQL



java



JS



kafka



mongoDB



MySQL



node



puppet



python



React Native



redis



Scala



spring



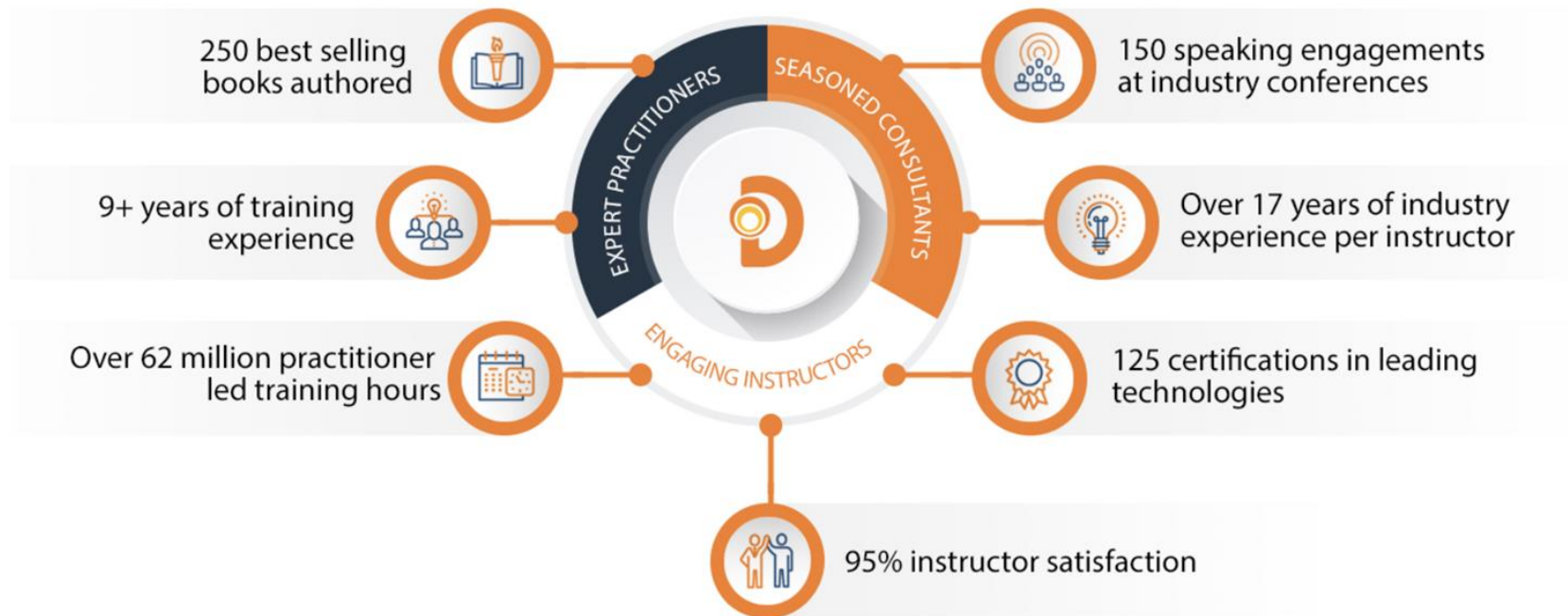
TS



AND MANY OTHER TRENDING TECHNOLOGIES



# World Class Practitioners





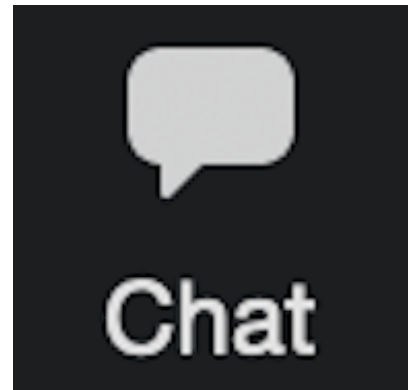
# Virtual Training Expectations for You



Arrive on time / return on time



Mute unless speaking



Use chat or ask  
questions verbally



# Virtual Training Expectations for Me

I pledge to:

- Make this as interesting and interactive as possible
- Ask questions in order to stimulate discussion
- Use whatever resources I have at hand to explain the material
- Try my best to manage verbal responses so that everyone who wants to speak can do so

Quick review of key Zoom features that may be helpful for our course



# Objectives

Upon completion of this course, you should be able to:

- Read and build Terraform projects
- Utilize reusable Terraform patterns
- Leverage security best practices for Terraform



# Let's Get to Know One Another

Tell me about you:


- Name
- Current role
- How long you've been at the company
- What's one thing you're hoping to get out of this course?

I'll tell you a little about me...





## v1.0.0

 hc-github-team-tf-core released this on Jun 8

### 1.0.0 (June 08, 2021)

Terraform v1.0 is an unusual release in that its primary focus is on stability, and it represents the culmination of several years of work in previous major releases to make sure that the Terraform language and internal architecture will be a suitable foundation for forthcoming additions that will remain backward compatible.

Terraform v1.0.0 intentionally has no significant changes compared to Terraform v0.15.5. You can consider the v1.0 series as a direct continuation of the v0.15 series; we do not intend to issue any further releases in the v0.15 series, because all of the v1.0 releases will be only minor updates to address bugs.

For all future minor releases with major version 1, we intend to preserve backward compatibility as described in detail in [the Terraform v1.0 Compatibility Promises](#). The later Terraform v1.1.0 will, therefore, be the first minor release with new features that we will implement with consideration of those promises.



## Semantic Versioning:

- Built around the concept of patch, minor and major change tracking
- Correspond to 3 different types of possible change to the framework
- Format:

*major #*

.

*minor #*

.

*patch #*



## Patch Change

- Rightmost digit in version number incremented
- Usually implies a bug fix
- When upgrading, represents relatively low risk



## Minor Change

- Middle digit in version number incremented
- More significant change or new functionality added
- However, should remain backward compatible on upgrade



# Major Change

- Leftmost digit in version number incremented
- Represents most significant type of change
- Potentially incompatible with previous versions



# Terraform Versioning

- Previously, semantic versioning worked a little differently for Terraform
- Prior to 1.0.\*, a change to the “minor” number looked more like “major”
- We’ve come a long way...v0.1.0 (2014) to v1.0.5 (Aug 2021)

<https://www.hashicorp.com/blog/announcing-hashicorp-terraform-1-0-general-availability>



## Other Good Sources for Learning

- Terraform has been around a while now, and is popular, so there are plenty of other sources for learning
  - Hashicorp's new learning portal:  
<https://learn.hashicorp.com/terraform>
  - Terraform repository for seeing the state of open issues:  
<https://github.com/hashicorp/terraform/issues>
  - Official Terraform docs:  
<https://www.terraform.io/docs/index.html>
  - Terraform registry for drilldown into provider-specific docs:  
<https://registry.terraform.io/browse/providers>



# What is Terraform?

- “infrastructure as code”
- *declarative* domain-specific language
  - what is declarative?
- used to describe *idempotent* resource configurations, typically in cloud infrastructure
- according to Hashicorp:
  - *Terraform enables you to safely and predictably create, change, and improve infrastructure. It is an open-source tool that codifies APIs into declarative configuration files that can be shared amongst team members, treated as code, edited, reviewed, and versioned*





# What is Terraform? (cont'd)

- open source CLI tool for *infrastructure automation*
- utilizes plugin architecture
  - extensible to any environment, tool, or framework and works primarily by making API calls to those environments, tools, or frameworks
- detects implicit dependencies between resources and automatically creates a dependency graph
- builds in dependency order and automatically performs activities in parallel where possible
  - ...sequentially for dependent resources



HashiCorp

**Terraform**



# Why Use Terraform?

- readable
- repeatable
- certainty (i.e., no confusion about what will happen)
- standardized environments
- provision quickly
- disaster recovery



# What Does Terraform (HCL) Look Like?

```
resource "aws_instance" "web" {  
    ami          = "ami-19827362728"  
    instance_type = "t2.micro"  
  
    tags = {  
        Name = "my-first-instance"  
    }  
}
```



# Exercise Prep: Let's Get Set Up

1. We will create an isolated (and consistent) development and execution environment where you can run Terraform
2. You will receive your student alias, access key, secret key, and console password (either via e-mail or Zoom chat)
3. Let's get these working in your development environment–this will allow you to create things and verify they exist in AWS
4. Access to your instructional repository:  
<https://github.com/KernelGamut32/terraform-fundamentals-public/tree/main/exercises/0-setup>

## ▼ example-terraform-project



.terraform (more on this directory later)



main.tf



outputs.tf



variables.tf



terraform.tfvars



others.auto.tfvars



\*.tf files get merged at runtime



terraform.tfvars and \*.auto.tfvars  
files get merged at runtime



# Terraform Project Structure

- ▶ examples → isolated units of reference implementation for modules
- ▶ modules → module definitions – can include subfolders
- ▼ environments → definitions of environment deployments
  - ▶ staging
  - ▶ production
- ▶ test → automated tests – e.g., terratest



# Hashicorp Configuration Language (HCL)



- The goal of HCL is to build a structured configuration language that is both human and machine friendly for use with command-line tools, but specifically targeted towards DevOps tools, servers, etc.
- Fully JSON compatible
- Made up of **stanzas** or **blocks**, which roughly equate to JSON objects. Each stanza/block maps to an object type as defined by **Terraform providers** (we'll talk more about providers later)
- <https://github.com/hashicorp/hcl>



# Terraform Project Content Types

## **\*.tf, \*.tf.json**

- HCL or JSON
- these files define your declarative infrastructure and resources

## **\*.tfstate**

- JSON files that store state, reference to resources
- created and maintained by terraform

## **terraform.tfvars, terraform.tfvars.json and/or \*.auto.tfvars, \*.auto.tfvars.json**

- HCL or JSON
- variable definitions in bulk
- (more to come on setting variable values at runtime)





- \*.tf files contain your **HCL declarative** definitions

```
resource "aws_instance" "web" {  
    ami          = "ami-19827362728"  
    instance_type = "t2.micro"  
  
    tags {  
        Name = "my-first-instance"  
    }  
}
```

- most **blocks** in your HCL represent a **resource** to be created/maintained by Terraform



- *resources* are key elements and captured as top-level objects (stanzas) in Terraform configuration files
- each resource stanza indicates the intent to *idempotently* create that resource
- body of resource contains configuration of attributes of that resource
- each provider (e.g., AWS, Azure, etc.) provides its own set of resources and defines the configuration attributes
- when a resource is created by Terraform, it's tracked in Terraform *state*
- resources can refer to attributes of other resources, creating implicit dependencies
  - dependencies trigger sequential creation

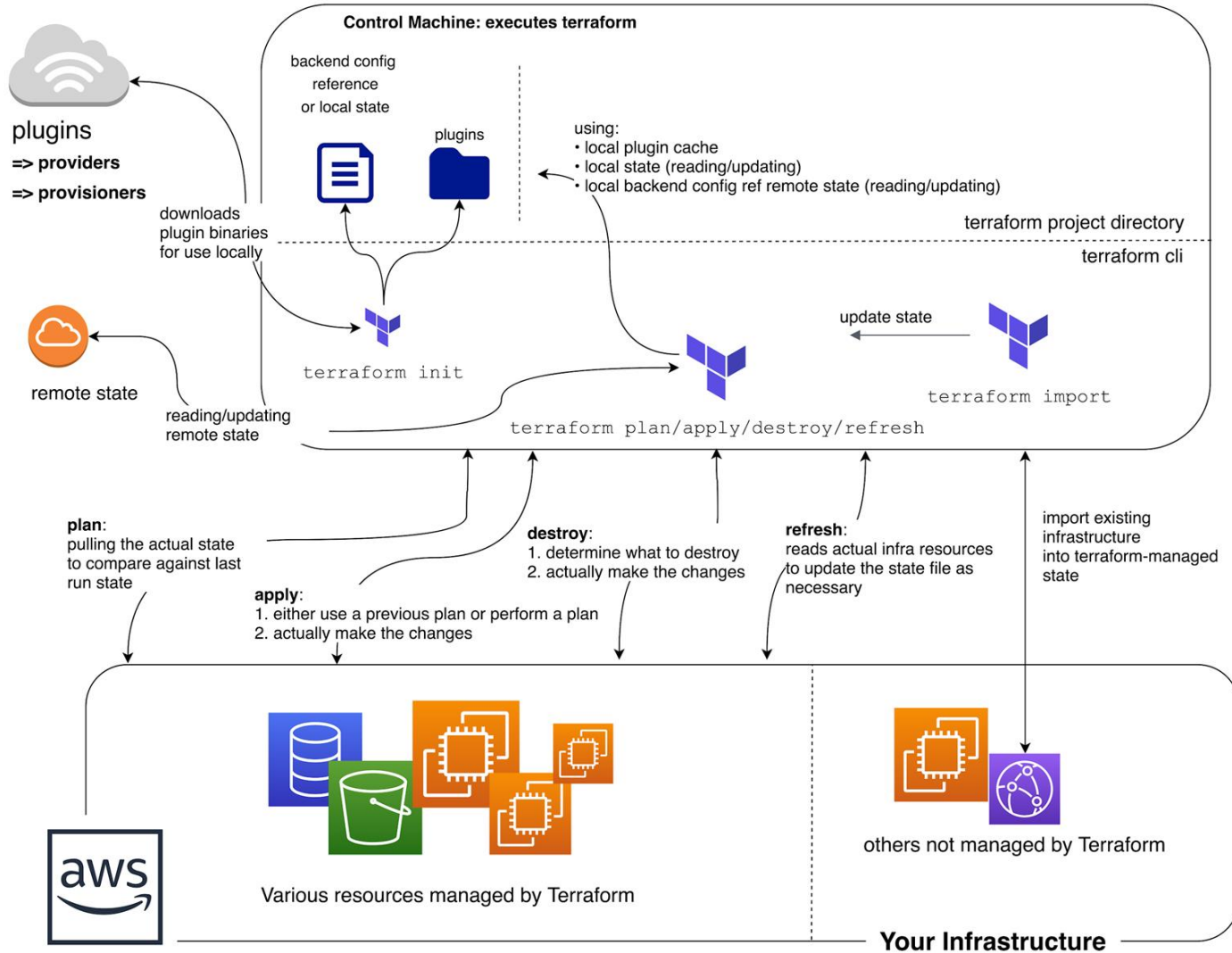


# Terraform Commands and the CLI

- The CLI is how you'll most often use terraform
  - `terraform init ...`
  - `terraform plan ...`
  - `terraform apply ...`
- And plenty more: `terraform --help` or <https://www.terraform.io/docs/commands/index.html>
- Third-party SDKs also available for running and interacting with Terraform (e.g., `scalr`, `terragrunt`, `terratest`)

Big picture look at

# Terraform Command Flow





- a special command, run before other commands/operations
- what does it do?
  - downloads required provider packages
  - downloads modules referenced in the HCL (more on modules later)
  - initializes state
    - local state: ensuring local state file(s) exist
    - remote state: more complex initialization (more on remote state later)
  - basic syntax check
- idempotent
- remember the **.terraform** directory?
  - **init** downloads the provider packages and modules to this directory
  - also, where state files live



# Exercise 1: First Terraform Project



## Exercise 1



# Extending Your Project

- Input Variables
- Locals
- Data Sources
- Provisioners
  - `remote-exec`
  - `local-exec`
  - `null_resource`



- enable interchangeable values to be stored centrally and referenced single or multiple times
- similar to variables in other languages
- declared in **variable** stanzas
- parsed first
- cannot interpolate or reference other variables
- allow for default values
- optionally specify value type, e.g.,
  - **List**, **Map**, **String**





- Input variable definitions support the following
  - default – provides default value if not specified; makes optional
  - type – type of value accepted for the variable
  - description – string description/documentation
  - validation – block for defining validation rules for input
  - sensitive – true or false; limits output as part of TF operations (plan or apply)



```
variable "instance_size" {  
    default      = "t2.micro"  
    type         = string # changed in 0.12  
    description = "Size of EC2 instance"  
}
```



# Example Variable Definition

```
variable "student_alias" {  
  type          = string  
  description = "Your student alias"  
  validation {  
    condition      = trimprefix(var.student_alias, "test") == var.student_alias  
    error_message = "Please do not use test aliases with this deployment."  
  }  
}
```



- mutable values that allow for interpolation and inference
- **CAN** reference variables and other locals
- **CAN'T** be set via arguments from the command line
- use them when a value is used in many places in your code and that value is likely to change
- don't overuse them or your code can be difficult to read



```
locals {  
  one      = "1"  
  twelve   = "${local.one}2"  
  onetwelve = "${local.one}${local.twelve}"  
}
```



- logical references to data objects stored externally to the **tfstate** file
- allows you to reference resources not created by Terraform
- examples
  - current default region in AWS CLI
  - AMI ID search
  - AWS ARN lookup
  - AWS VPC CIDR range



# Data Source Example: AWS AMI Lookup

```
data "aws_ami" "latest-ubuntu" {
  most_recent = true
  owners      = ["099720109477"]

  filter {
    name     = "name"
    values   = ["ubuntu/images/hvm-ssd/ubuntu-xenial-16.04-amd64-server-*"]
  }

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



- allow you to run commands during instance provisioning that are run on create, recreate, or taint correction (explained later), but not every time **terraform apply** is run
- ties custom logic to idempotent resources
- types
  - local
  - remote
  - **chef**
- connectors
  - SSH
  - WinRM





# Provisioner Example: local-exec

```
resource "aws_instance" "web" {
  ami           = "ami-19827362728"
  instance_type = "t2.micro"

  tags {
    Name = "my-first-instance"
  }

  provisioner "local-exec" {
    command = "echo `created instance`"
  }
}
```



# Provisioner Example: remote-exec

```
resource "aws_instance" "web" {  
  ...  
  
  provisioner "remote-exec" {  
    inline = [  
      "sudo sed -i  
        's/^PasswordAuthentication.*/PasswordAuthentication yes/'  
        /etc/ssh/sshd_config",  
      "sudo service sshd restart",  
      "wget https://repo.anaconda.com/Anaconda3-Linux-x86_64.sh",  
      "sh Anaconda3-Linux-x86_64.sh -b"  
    ]  
  }  
}
```



## Provisioner example: null\_resource

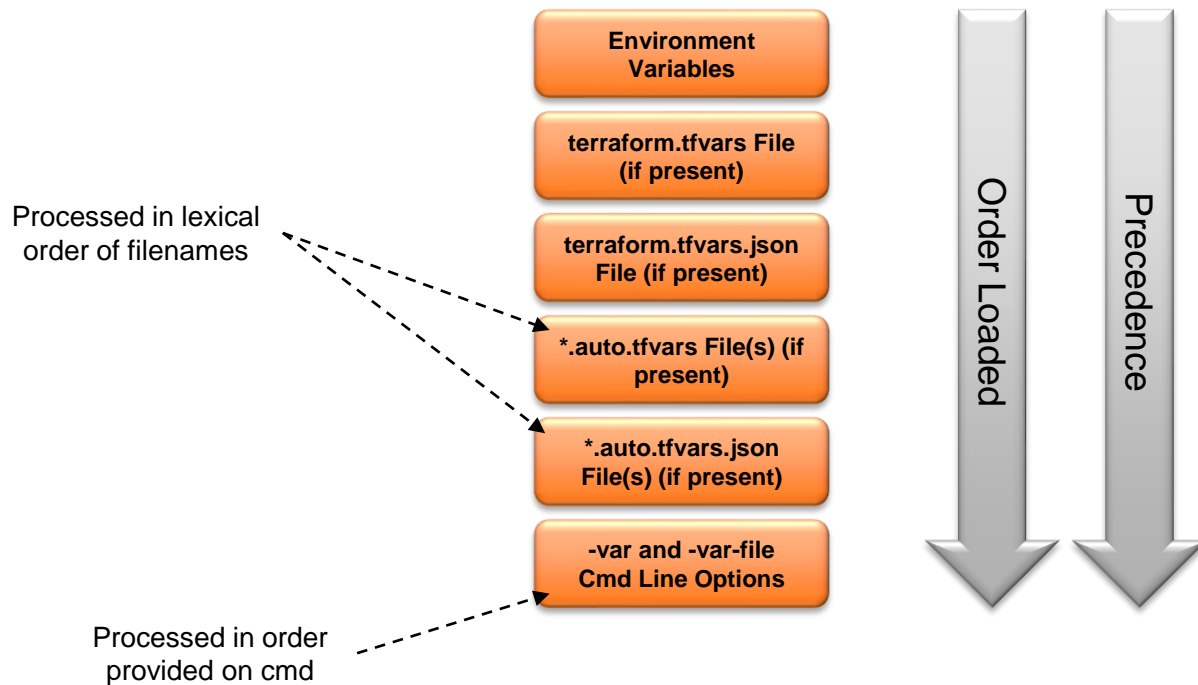
```
resource "null_resource" "first-tf-run" {  
  provisioner "local-exec" {  
    command = "echo `this will run on first tf  
apply`"  
  }  
}
```



- Multiple options
  - using environment variables (prefixed with “TF\_VAR\_”)
  - defining inputs in a terraform.tfvars file
  - defining inputs in a terraform.tfvars.json file
  - defining inputs in one or more \*.auto.tfvars files
  - defining inputs in one or more \*.auto.tfvars.json files
  - -var and -var-file options on the command-line



# Providing Values for Input Variables





# Providing Values for Input Variables

- primarily used when executing Terraform via CLI
- not really used with Terraform Enterprise
- can “push” those variables + values to Enterprise (in files)
- but manage from “Variables” section of the environment



## Exercise 2: Using Variables

# Exercise 2



# How Terraform Works

- state and how to query it
- computing plans
- executing plans (**terraform apply**)





- stores information about resources that are created by Terraform
  - also includes values computed by the provider APIs
- local file
  - **.tfstate**
- or backends are also available...



- determines how state is loaded and how operations like **apply** are executed
- enables non-local file state storage, remote execution, etc.
- why use a backend?
  - can store their state remotely and protect it to prevent corruption
    - some backends, e.g., *Terraform Cloud* automatically store all revisions
  - keep sensitive information off local disk
  - remote operations
    - apply can take a *LONG* time for large infrastructures



- examples
  - S3
  - swift
  - http
  - Terraform Enterprise
  - etc.

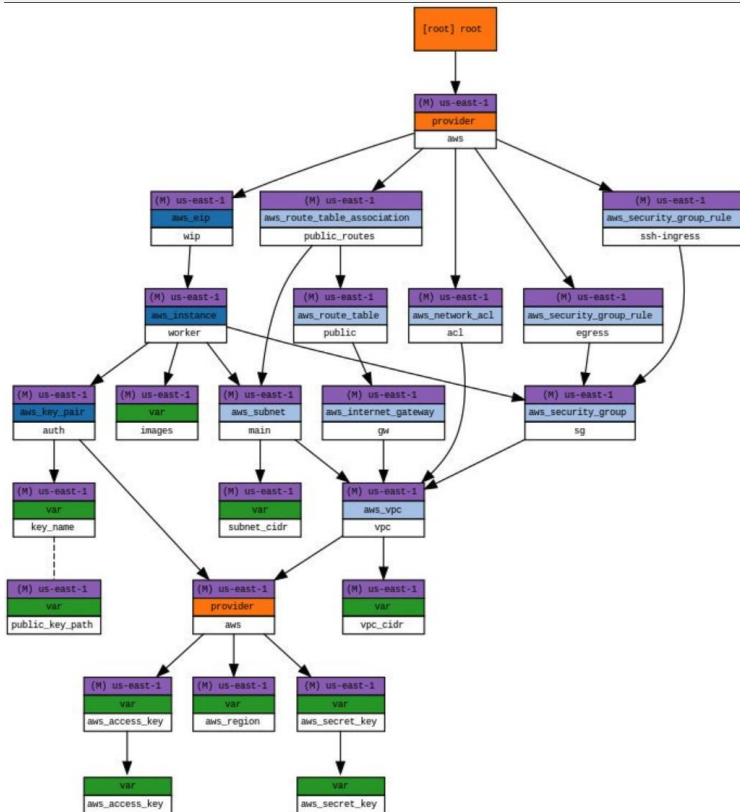


# How to Query or See the Current State

- CLI
  - `terraform show [-json]`  
<https://www.terraform.io/docs/commands/show.html>
- Remote State Data Type  
[https://www.terraform.io/docs/providers/terraform/d/remote\\_state.html](https://www.terraform.io/docs/providers/terraform/d/remote_state.html)



# Visualizing Graph Outputs







# Executing Plans: terraform apply

- What does **terraform apply** do?
  - syntax check
  - check for init
  - refresh state
  - execute plan
  - ask for input
  - execute changes

# Exercise 3





- responsible for understanding API interactions and exposing resources
- Hashicorp helps companies create providers to be added to ecosystem
- declared in HCL config files as a **provider** stanza
- each Terraform project can have multiple providers, even of the same type
- describes resources, their inputs, outputs, and the logic to create and change them
- many options
  - AWS, GCP, Azure, and many many others
  - providers available for non-infra services as well such as gmail, MySQL, and Pagerduty



- provider documentation
  - <https://www.terraform.io/docs/providers/aws/index.html>
- HUGE amount of resources
- something like 8 resources per service on average



# Configuring the Provider

```
provider "aws" {  
    region      = "us-west-1"  
    access_key  = "[your access key]"  
    secret_key  = "[your secret access key]"  
}
```



# Reuse Patterns in Terraform

- **Workspaces:** separate state files for the same HCL
- **Outputs:** automated use of terraform-managed resources
- **Modules:** packaged HCL for reuse



- Workspaces allow you to use the same configuration (HCL/project) for multiple states
  - example: AWS Developer VPCs—each developer could have an identical environment as defined by the configuration, but each managed by a different state by way of separate workspaces
- nothing more than separately-named state files
- both local and remote state backends support workspaces



- *inputs* to a Terraform config are declared with variables stanzas
- *outputs* are declared with a special output stanza
- can be referenced through the modules interface or the CLI



- Output variable definitions support the following
  - value – value to be returned as output
  - description – string description/documentation
  - sensitive – true or false; limits output as part of TF operations (plan or apply)



```
output "instance_public_ip" {  
    value = aws_instance.web.public_ip  
}
```





- *modules* are a critically important concept in Terraform
- basically, every Terraform working directory, as long as it has variable stanzas, is a module
- this allows developers to compose reusable blocks of configuration and reference them with module stanzas



- allow for modularized configuration (create separate modules for different parts of configuration), aka module composition
- every project has at least one module (the “root” module), but root can have a tree of children
- child modules have input variables passed in from parent module
- modules can be defined by configuration files in local filesystem or remote source



- can publish modules in [Terraform registry](#) to make them easy to find
  - **source** attribute identifies location of module, e.g.,

```
module "webserver" {  
    source = "../webserver" # module in this dir  
    instance_type = "t2.micro"  
}
```
- most attributes of a module are input variables passed in from parent
- module's outputs can be accessed and used by parent (and passed to other child modules of the parent)



- Terraform allows the user to pull modules from various locations
  - local paths
  - Github
  - Terraform Registry
  - Bitbucket
  - HTTP
  - S3 Buckets
- More info
  - <https://www.terraform.io/docs/modules/sources.html>

```
module "consul" {  
  source = "github.com/hashicorp/example"  
}
```

```
module "consul" {  
  source = "hashicorp/consul/aws"  
  version = "0.1.0"  
}
```



```
variable "thing" {  
    type = string  
}  
  
resource null_resource "null" {  
    provisioner local-exec {  
        command = "echo ${var.thing}"  
    }  
}
```



```
module "my_module" "printer" {  
  source = "../my_module"  
  
  # this is a variable passed into module  
  thing = "this should be printed"  
}
```



# Exercise 4



## Exercise 5: Interacting with Providers



# Exercise 5





# Exercise 6



## Experimentation Time: Webserver

- Let's first do this by hand, then use Terraform
- Create an EC2 instance, type **t2.micro**, whatever distro you like
  - provision this instance to install **nginx**
  - make sure we can access **nginx** from the outside world
  - use online docs for help, use each other, and I'm here too if you need



## Experimentation Time: Webserver (cont'd)

- You can go in many different directions as you solve this, and there are plenty of things to play with along the way and after, some ideas:
  - imagine your Terraform code to spin up this instance needed to be reused, what are your options—make it reusable!
    - **hints:** workspaces, package as a module
  - pretend that some other automation needed the public IP from the created instance, how would you do this?
    - **hints:** outputs, and play with wrapping Terraform commands in a parent script (e.g., bash or Python)
  - ...and finally, ANYTHING else you'd like to start learning more about, **terraform graph** maybe?

- Most errors fall into one of four types
  - Process Errors
  - Syntax Errors
  - Validation Errors
  - Passthrough Errors



- errors due to process not being followed
- e.g.,
  - running **apply** before **init**
  - variables not fully populated



- caused by an error in syntax, e.g.,
  - HCL codebase syntax or parameter errors
  - incorrect usage of built-in functions
  - type errors



- preliminary validation built into provider occurring before plan
- usually more detailed

- errors received from provider or third-party API while in process of refresh, plan, apply, etc.
  - usually most difficult to troubleshoot
  - requires knowledge of provider's tech (e.g., AWS)



- **terraform validate**
  - performs a syntax check on all terraform files in the directory
  - displays an error if any of the files doesn't validate
  - does *NOT* check formatting
  - what does it check...?



- invalid HCL syntax (e.g., missing quote or equal sign)
- invalid HCL references (e.g., variable name or attribute which doesn't exist)
- same provider declared multiple times
- same module declared multiple times
- same resource declared multiple times
- invalid module name
- interpolation used in places where it's unsupported (e.g., variable, **depends\_on**, **module.source**, **provider**)
- missing value for a variable (none of **-var foo=...** flag, **-var-file=foo.vars** flag, **TF\_VAR\_foo** environment variable, **terraform.tfvars**, or default value in the configuration)



- rewrites Terraform files in a canonical format/style
- by default, scans the current directory for configuration files
  - if the dir argument is provided then it will scan that given directory instead
  - if dir is a single dash (-) then **fmt** will read from standard input



- generates a visual representation of either a configuration or execution plan
  - output is in DOT format, which can be used by GraphViz to generate charts:

<https://www.terraform.io/docs/internals/graph.html>

- e.g.,

```
terraform graph | dot -Tsvg > graph.svg
```



- creates an interactive console for testing interpolations
  - similar to running the Python interpreter in interactive mode
- great for testing complex conditionals



## Exercise 7: Error Handling, Troubleshooting



# Exercise 7



- embedded within strings in Terraform, whether you're using the HCL or JSON, you can interpolate other values.
  - These interpolations are wrapped in `${...}`, such as `${var.foo}`
- allows you to reference variables, attributes of resources, call functions, etc.
- simple math like
  - `${count.index + 1}`
- allows for conditional statements
- <https://www.terraform.io/docs/language/expressions/strings.html>



- built-in functions:
  - Terraform ships with built-in functions
  - called with the syntax **name(arg, arg2, ...)**
  - e.g., to read a file:  
`${file("path.txt")}`
  - <https://www.terraform.io/docs/language/functions/index.html>





- interpolations may contain conditionals to branch on the final value
- syntax

**CONDITION ? TRUEVAL : FALSEVAL**



- **string**
  - use the var prefix followed by the variable name
  - e.g., `${var.foo}` is how you would use the variable in HCL for interpolation or reference
- **number**
  - can be referenced as a number, so in arithmetic for example  
`${var.foo + 1}`
- **bool**
  - can be referenced as a boolean in logic, so something like  
`${var.foo == true ? "foo is true" : "foo is false"}`



- **list(<type>)**
  - ordered list of things, i.e., array
    - e.g., `${var.subnets}` would get the value of the subnets *list*
    - you can also return list elements by index: `${var.subnets[0]}`
- **set(<type>)**
  - similar to a list, but: requires a type, unique values, no ordering
- **map(<type>)**
  - a collection of values where each is identified by a string
  - e.g., `${var.amis["us-east-1"]}` would get the value of the **us-east-1** key within the **amis** map variable

- **object**({ <attr name> = <type>, ... })
  - like many other language object types, with properties containing other values
- **tuple**([<type>, ...])
  - very similar to a list, mixed strictly defined typed list of things



- resources can be duplicated or conditionally created via the count parameter

```
resource "aws_instance" "web" {  
  count      = 2  
  ami       = "${var.ami}"  
  instance_type = "${var.instance_type}"  
  
  tags {  
    Name = "web-${count.index}"  
  }  
}
```



- attributes of current resource
  - syntax is **self.ATTRIBUTE**
  - e.g., **\${self.private\_ip}** interpolates resource's private IP address



- attributes of other resources
  - syntax is **TYPE.NAME.ATTRIBUTE**
  - **`${aws_instance.web.id}`**
    - interpolate ID attribute from the **aws\_instance** resource **web**
    - if resource has a count attribute set, you can access individual attributes with a zero-based index, such as  
**`${aws_instance.web[0].id}`**
    - or use the splat syntax to get a list of all the attributes:  
**`${aws_instance.web[*].id}`**

- attributes of a data source
  - `data.TYPE.NAME.ATTRIBUTE`
  - `${data.aws_ami.ubuntu.id}`
    - interpolate `id` attribute from the `aws_ami` data source `ubuntu`
    - if data source has a `count` attribute set, access individual attributes with a zero-based index, e.g.,  
`${data.aws_subnet.example[0].cidr_block}`
    - or use the splat syntax to get a list of all the attributes:  
`${data.aws_subnet.example[*].cidr_block}`





- Referencing values output from another module
  - `module.MODULE_NAME.MODULE_OUTPUT_NAME`



# Resource Example w/Conditional

```
resource "aws_instance" "web" {  
    ami          = "${var.ami}"  
    instance_type = "${var.instance_type}"  
  
    tags {  
        Name = "${var.env == "production" ? "production-  
web" : "staging-web"}"  
    }  
}
```



# Exercise 8



# Keeping Terraform in Sync with Infra

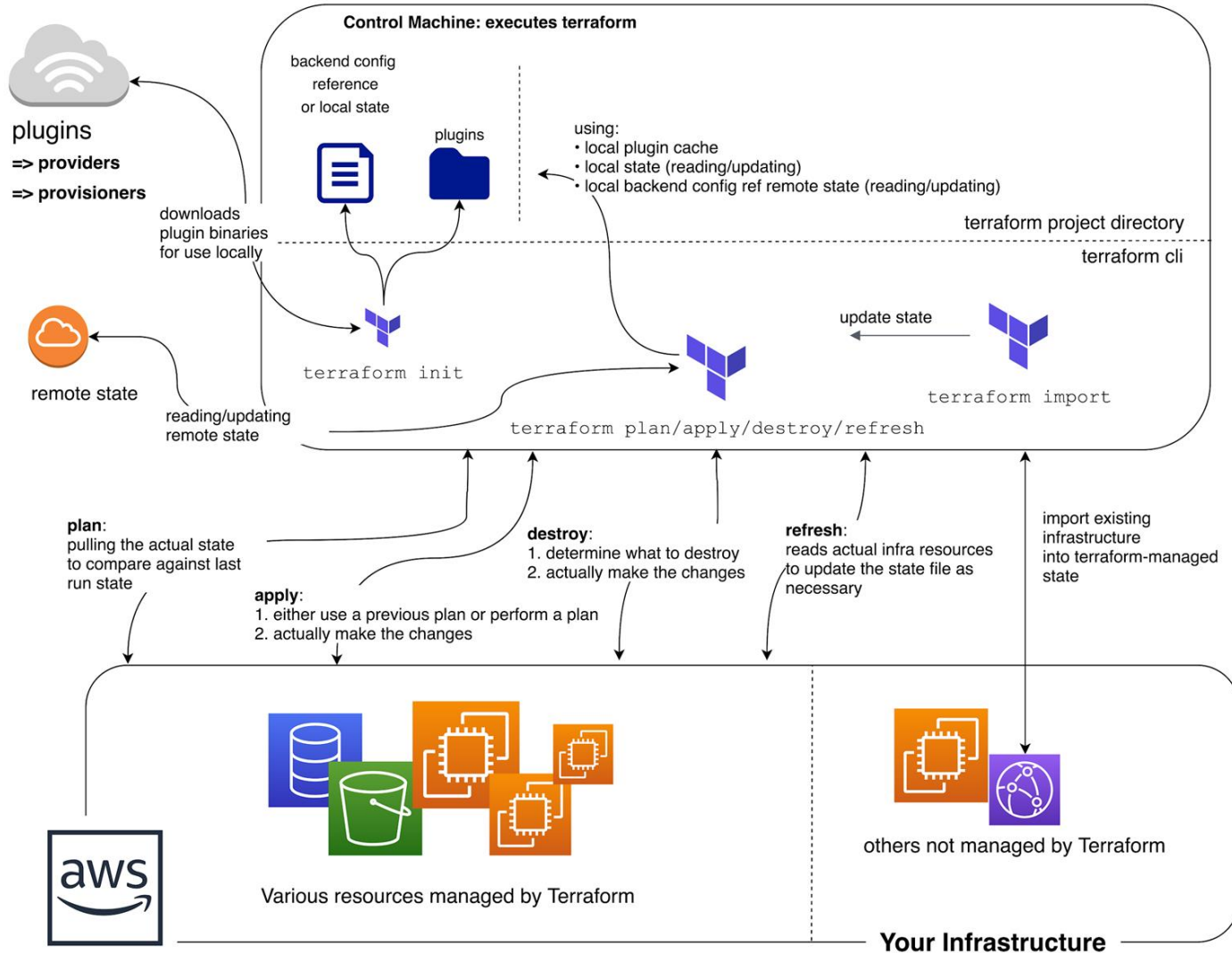
- configuration drift
  - things change!
  - Terraform can bring those things back in line naturally
- **plan**
  - when executing a plan, Terraform can output machine readable syntax (exit codes) that can be used to monitor for manual infra changes
  - if the infra changes, plans will suddenly detect drift and inform alarms
- **apply**
  - thanks to Terraform's idempotency, corrections are natural and easy



- what if we want to keep the changes?
- you can import them
  - use **terraform import** to pull in the changes to the state
  - must also change the Terraform config to match any changes
  - if you have a clean plan with no planned changes, you were successful
- e.g.,  
`terraform import aws_instance.my_instance i-abcd1234`

Big picture look at

# Terraform Command Flow





# Exercise 9



- can set attributes, outputs and locals to expressions
- expressions can refer to
  - literal values or complex literal values: **true**, **13**, **“us-west1”**, **[1, 2]**, **{a:1, b:2}**
  - resource or data source attributes: **<RESOURCE TYPE>.<NAME>**, **data.<DATA TYPE>.<NAME>**
  - type indices: **local.list[3]**, **local.object.attrname**, **local.map["keyname"]**
  - variables: **var.<NAME>**
  - locals: **local.<NAME>**
  - ...





- module outputs: `module.<MODULE NAME>.<OUTPUT NAME>`
- path variables: `path.module`, `path.root`, `path.cwd`
- workspace setting: `terraform.workspace`
- built-in functions using any of the above as arguments
  - `max(5, 12, var.my_value)`
- arithmetic, logical, or comparison operators combining the above
- conditional expressions: `var.a != "" ? var.a : "default-a"`
- string template interpolation: `"Hello, ${var.name}!"`
- string template directives:  
`"Hello, %{ if var.name != "" }${var.name}%{ else }unnamed%{ endif }!"`

- Multi-line string templates
- Looping string directive (**for/endfor**)

```
<<EOT
%{ for ip in aws_instance.example.*.private_ip }
server ${ip}
%{ endfor }
EOT
```



- Splat syntax

```
var.list[*].id
```

```
var.list[*].interfaces[0].name
```



- **for** expressions to convert lists/maps/tuples/objects to other lists/maps/tuples/objects

```
[for s in var.list : upper(s)]
```

```
{for s in var.list : s => upper(s)}
```

```
[for s in var.list : upper(s) if s != ""]
```

```
[for k, v in var.map : length(k) + length(v)]
```

```
{for s in var.list : substr(s, 0, 1) => s... if s != ""}
```



- `dynamic` blocks

```
resource "aws_security_group" "example" {  
  name = "example" # can use expressions here  
  
  dynamic "ingress" {  
    for_each = var.service_ports  
    content {  
      from_port = ingress.value  
      to_port   = ingress.value  
      protocol  = "tcp"  
    }  
  }  
}
```



- resources, data sources, modules, and outputs can have meta-arguments (available across all types of all providers)
- modules have: `source`, `version`, `providers`
- outputs have: `depends_on`
- resources have: `depends_on`, `count`, `for_each`, `provider`, `lifecycle`, `provisioner` (`provisioner` can have `connection` inside)
- data sources have same as resources except for `lifecycle`
- `depends_on` forces a dependency on another object even if no implicit dependency by referring to an attribute of another object
- `lifecycle` controls how resources are modified when configuration changes
- `for_each` is like `count` except it iterates over a set (unordered list) or map; has `each.key`, `each.value` instead of `count.index` to refer to each index



- `providers` and `provider` are used when dealing with multiple providers in the same configuration

```
provider "aws" {  
  alias = "usw1"  
  region = "us-west-1"  
}  
  
provider "aws" {  
  alias = "usw2"  
  region = "us-west-2"  
}  
  
module "tunnel" {  
  source = "./tunnel"  
  providers = {  
    aws.src = "aws.usw1"  
    aws.dst = "aws.usw2"  
  }  
}
```

```
# default configuration  
provider "google" {  
  region = "us-central1"  
}  
  
# alternative, aliased configuration  
provider "google" {  
  alias = "europe"  
  region = "europe-west1"  
}  
  
resource "google_compute_instance" "example" {  
  # This "provider" meta-argument selects the google provider  
  # configuration whose alias is "europe", rather than the  
  # default configuration.  
  provider = google.europe  
  
  # ...  
}
```



- Backends are the concept that terraform uses to store state
- Defaults to local tfstate file
- Others available:
  - S3
  - HTTP
  - Consul
  - Artifactory
  - Etcd
  - Terraform Enterprise
  - etc...





Because this course is about Terraform with AWS specifically, let's talk about the S3 state backend:

- Uses a bucket and path to an object (the state file) in the bucket for a central place to store state
- Supports locking using an AWS Dynamo DB table
- See <https://www.terraform.io/docs/backends/types/s3.html> for more info



# Exercise 10



## Exercise 11: Running an Application in AWS



# Exercise 11



Really two levels:

- Security at the IaC (Infrastructure-as-Code) level
- Secure configuration of the target resources (e.g., AWS components)



At the target resource level:

- use best practices as defined by cloud provider (e.g., AWS or Azure Well Architected Framework)
- utilize network boundaries and controls (VPC's, subnets, security groups)
- utilize TLS and encryption at rest and in transit
- utilize API gateways and firewalls to protect at the perimeter
- mTLS is a great option for service-to-service integration
- practice the principles of “least privilege” and defense in depth



Common missteps at the target resource level:

- using default configurations not optimized for security
- not sufficiently leveraging logging and not managing sensitive data in logs
- using unencrypted data stores
- using less secure protocols for network communications
- not effectively accounting for both AuthN and AuthZ



At the IaC (Terraform) level:

- apply proper controls by environment and for state at each environment
- be aware of the 3<sup>rd</sup> party modules used and any vulnerabilities
- use variables as control points in the configuration
- shift security left – use static and dynamic scanning tools for security
- look for potential security issues in the Terraform plan







What is it?

- self-hosted distribution of Terraform Cloud
- private instance of Terraform Cloud for added security & control
- no resource limits
- additional features – audit logging, SAML SSO, etc.



## Benefits:

- improvements in operational efficiencies
- controlling cloud costs
- reducing risk



Improvements in operational efficiencies:

- graphical access to workspaces and runs within
- graphical access to variables and outputs
- graphical access to remote state
- log output from each state of workflow



Controlling cloud costs:

- cost estimation built into workflow
- integration with Terraform Sentinel policies brings control
- policies can be used to prevent overprovisioning, integration of an approval step for expensive resources, etc.



## Reducing risk:

- Terraform Sentinel policies help with enforcement of security best practices
- private module registry offers security for IaC IP
- facilitates team coordination
- adds audit logging and logging of approvals for traceability
- capabilities of Terraform Cloud but self-hosted and controlled



## Integration with VCS:

- supports direct integration with source control (like GitHub)
- as configuration updates are checked in, workflow in UI able to execute





What is it?

- embedded policy-as-code framework
- integrated into Terraform Cloud (and by extension Terraform Enterprise)
- enables fine-grained, logic-based policy decisions for securing IaC





## Process:

- define – uses a proprietary policy language (kinda Go “like”)

```
1 import "time"
2
3 # Validate time is between 8 AM and 4 PM
4 valid_time = rule { time.now.hour >= 8 and time.now.hour < 16 }
5
6 # Validate day is M - Th
7 valid_day = rule {
8     time.now.weekday_name in ["Monday", "Tuesday", "Wednesday", "Thursday"]
9 }
10
11 main = rule { valid_time and valid_day }
```

- manage – via VCS integration or policy upload through API
- enforcement – adding policy checks to runs

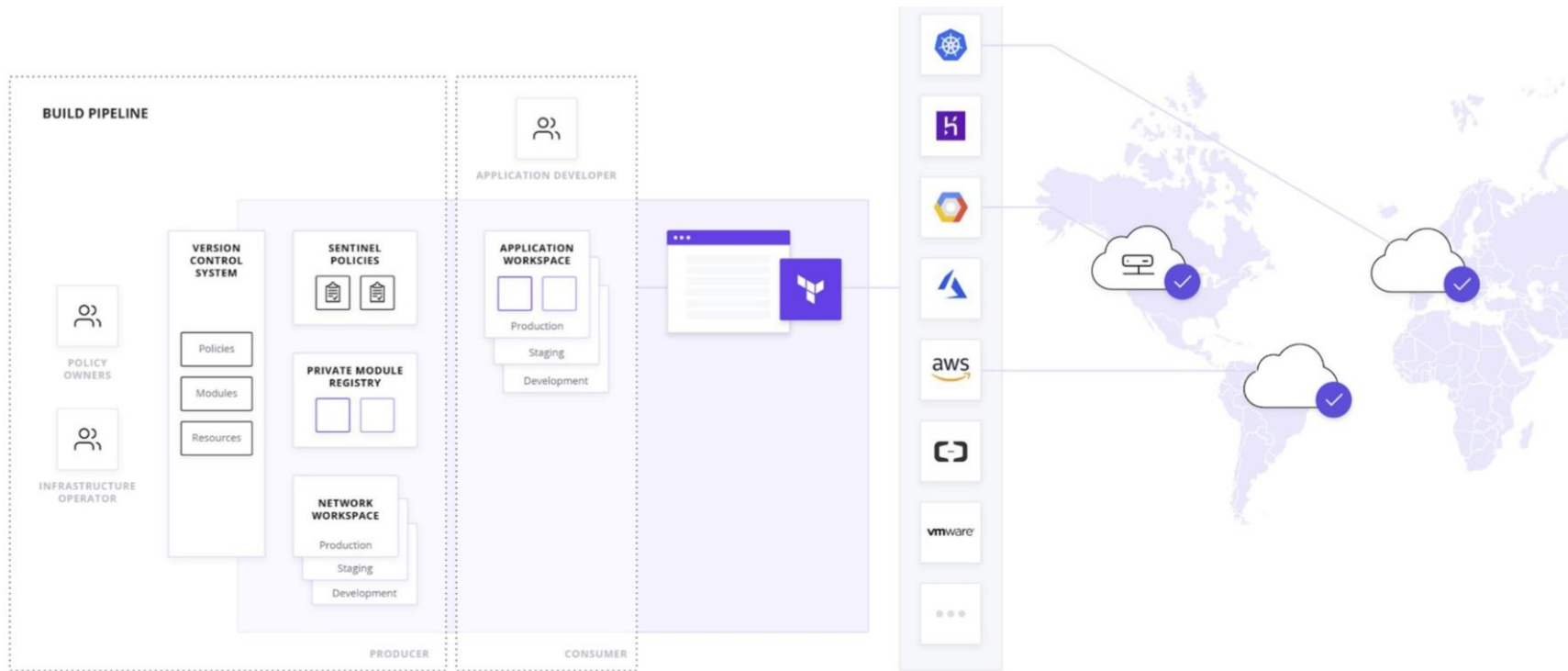


## Mocking & Testing

- in Terraform Cloud, able to generate mock data for a run
- mock data can be used with Sentinel CLI to test policies prior to deployment



# Terraform Enterprise – Reference Arch





*THANK YOU*



