What is Infrastructure as Code?

The Problem with Manual Configuration

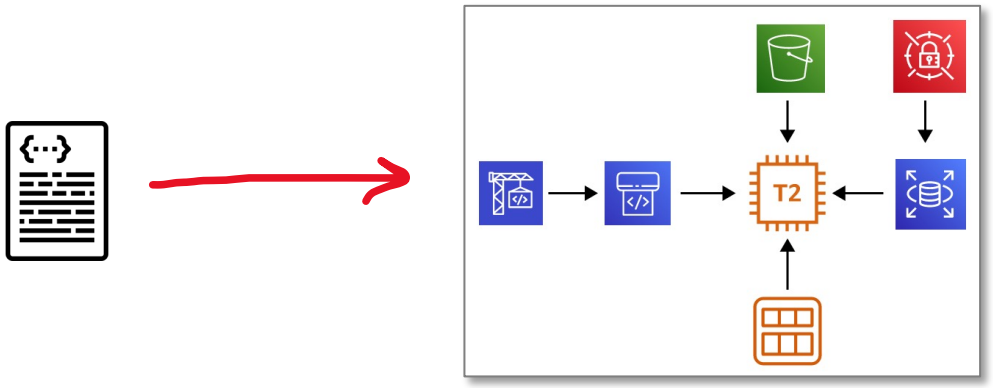
Manually configuring your cloud infrastructure allows you easily start using new service offerings to quickly prototype architectures however it comes with many downsides:

- Its easy to mis-configure a service though human error
- Its hard to manage the expected state of configuration for compliance
- Its hard to transfer configuration knowledge to other team members

Infrastructure as Code (IaC)

You write a configuration script to **automate** **creating, updating or destroying** cloud infrastructure.

- IaC is a **blueprint** of your infrastructure.
- IaC allows you to easily **share, version or inventory** your cloud infrastructure.



Popular Infrastructure as Code tools (IaC)

Declarative

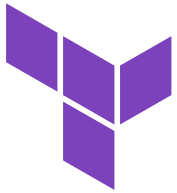
- What you see is what you get. ***Explicit***
- More verbose, but zero chance of mis-configuration
- Uses scripting languages eg. JSON, YAML, XML

ARM Templates
Supports only Azure

Azure Blueprints
Supports only Azure
Manages relationship between services

CloudFormation
Only for AWS

Cloud Deployment Manager
Supports on Google Cloud



Terraform
Supports many cloud service providers (CSPs) and cloud services.

Imperative

- You say what you want, and the rest is filled in. ***Implict***
- Less verbose, you could end up with misconfiguration
- Does more than Declarative
- Uses programming languages eg. Python, Ruby, JavaScript

AWS Cloud Development Kit (CDK)
Supports only AWS
Many built-in templates for opinionated best practices

Pulumi
Supports AWS, Azure, GCP, K8

Declarative+

Terraform is declarative but the Terraform Language features **imperative-like functionality.**

Declarative		Imperative
YAML, JSON, XML	HCL-ish (Terraform Language)	Ruby, Python, JavaScript ….
Limited or no support for imperative-like features. In some cases you can add behaviour by extending the base language. E.g. CloudFormation Macros.	Supports: • Loops (For Each) • Dynamic Blocks • Locals • Complex Data Structure • Maps, Collections	Imperative features is the utility of the entire feature set of the programming language.

Infrastructure Lifecycle

What is Infrastructure Lifecycle?

a number **of clearly defined and distinct work phases** which are used by DevOps Engineers to **plan, design, build, test, deliver, maintain and retire** cloud infrastructure.

What is Day 0, Day 1 and Day 2?

Day 0-2 is a simplified way to describe phases of an infrastructure lifecycle

- Day 0 — Plan and Design
- Day 1 — Develop and Iterate
- Day 2 — Go live and maintain

Days do not literally mean **a 24 hour days** and is just a broad way of defining where a Infrastructure project would be.

Infrastructure Lifecycle

How does IaC enhance the Infrastructure Lifecycle?

Reliability

IaC makes changes **idempotent**, consistent, repeatable, and predictable.

Idempotent

No matter how many times you run IaC, you will always end up with the same state that is expected

Manageability

- enable mutation via code
- revised, with minimal changes

Sensibility

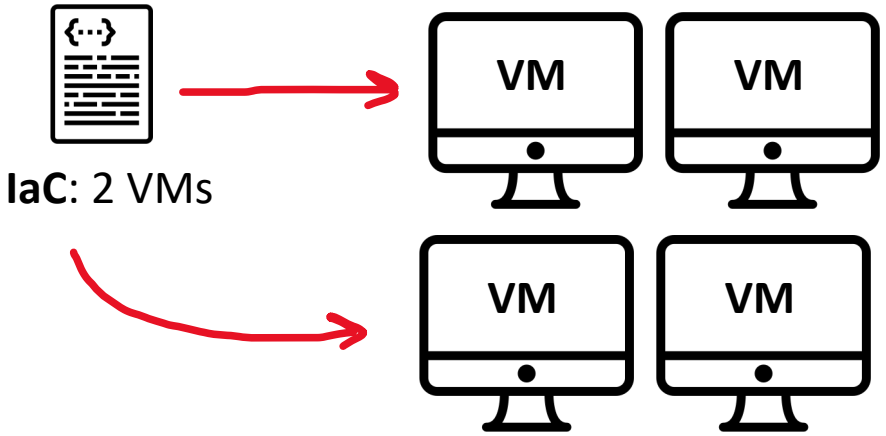
avoid financial and reputational losses to even loss of life when considering government and military dependencies on infrastructure.

Non-Idempotent vs Idempotent

Non-Idempotent

When I deploy my IaC config file it will **provision** and **launch** 2 virtual machines

When I update my IaC and deploy again, I will end up with 2 new VMs with a total of 4 VMs

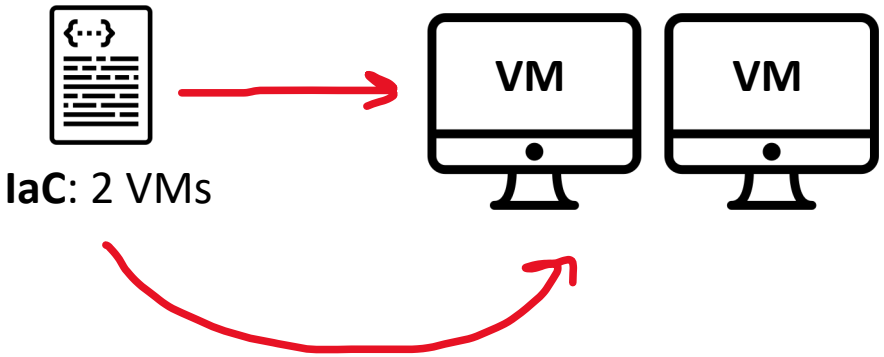


We expect a state of **2**
We end up with **4**

Idempotent

When I deploy my IaC config file it will **provision** and **launch** 2 virtual machines

When I update my IaC and deploy again, it will update the VMs if changed by **modifying or deleting and creating new VMs**



We expect a state of **2**
We end up with **2**

Provisioning vs Deployment vs Orchestration

Provisioning
To prepare a server with systems, data and software, and make it ready for network operation.
Using Configuration Management tools like Puppet, Ansible, Chef, Bash scripts, PowerShell or Cloud-Init you can provision a server.
When you launch a cloud service and configure it you are “provisioning”

Deployment
Deployment is the act of delivering a version of your application to run a provisioned server.
Deployment could be performed via AWS CodePipline, Harness, Jenkins, Github Actions, CircleCI

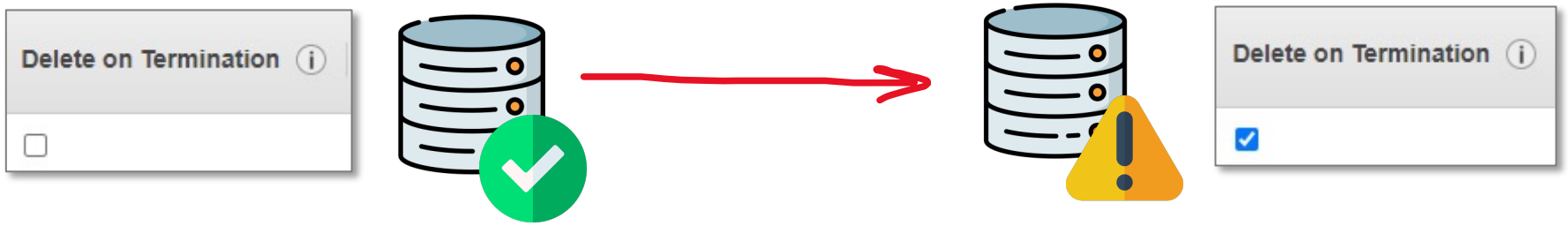
Orchestration
Orchestration is the act of coordinating multiple systems or services.
Orchestration is a common term when working with microservices, Containers and Kubernetes.
Orchestration could be Kubernetes, Salt, Fabric

Configuration Drift

Configuration Drift is when provisioned infrastructure has **an unexpected configuration change** due to:

- team members manually adjusting configuration options
- malicious actors
- side affects from APIs, SDK or CLIs.

eg, a junior developer turns on Delete on Termination for the production database.



Configuration Drift going unnoticed could be loss or breach of cloud services and residing data or result in interruption of services or unexpected downtime.

Configuration Drift

How to detect configuration drift?

- A compliance tool that can detect misconfiguration eg. AWS Config, Azure Policies, *GCP Security Health Analytics
- Built-in support for drift detection eg. AWS CloudFormation Drift Detection
- Storing the expected state eg. Terraform state files

How to correct configuration drift?

- A compliance tool that can remediate (correct) misconfiguration e.g. AWS Config
- Terraform refresh and plan commands
- Manually correcting the configuration (not recommended)
- Tearing down and setting up the infrastructure again

How to prevent configuration drift?

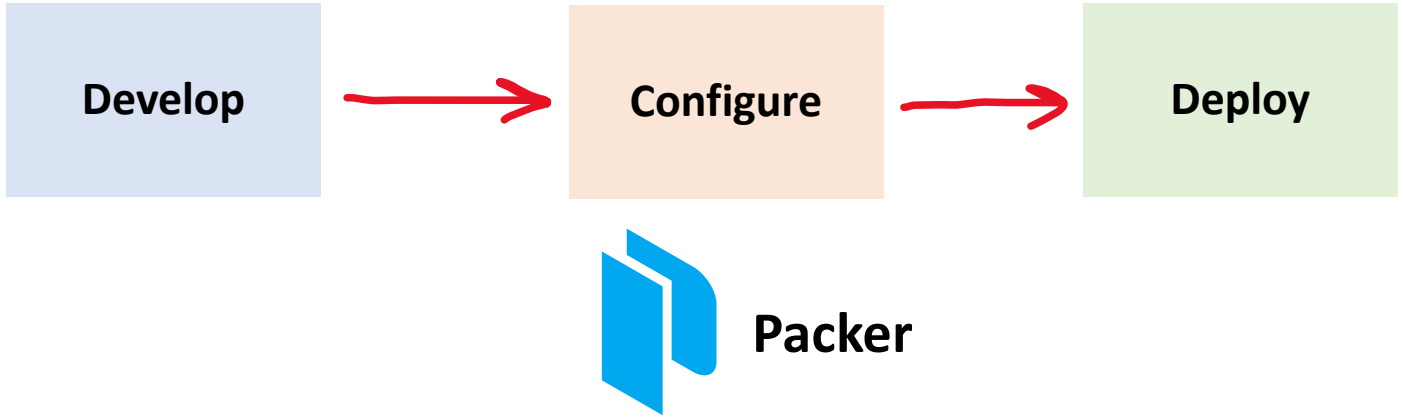
- **Immutable infrastructure**, always create and destroy, never reuse, Blue, Green deployment strategy.
    - Servers are never modified after they are deployed
        - Baking AMI images or containers via AWS Image Builder or HashiCorp Packer, or a build server eg. GCP Cloud Run
- Using GitOps to version control our IaC, and peer review every single via Pull Requests change to infrastructure

Mutable vs Immutable Infrastructure

Mutable Infrastructure

A Virtual Machine (VM) is deployed and then a Configuration Management tool like Ansible, Puppet, Chef, Salt or Cloud-Init is used to configure the state of the server

Immutable Infrastructure



A VM is launched and provisioned, and then and it is turned into a Virtual Image, stored in image repository, that image is used to deployed VM instances

Immutable Infrastructure Guarantee

Terraform encourages you towards an Immutable Infrastructure architect so you get the following guarantees.

Cloud Resource Failure – What if an EC2 instance fails a status check?

Application Failure – What if your post installation script fails due to change in package?

Time to Deploy - What if I need to deploy in a hurry?

Worst Case Scenario

- Accidental Deletion
- Compromised by malicious actor
- Need to Change Regions (region outage)

No Guarantee of 1-to-1

Every time Cloud-Init runs post deploy there is no guarantee its one-to-one with your other VMs.

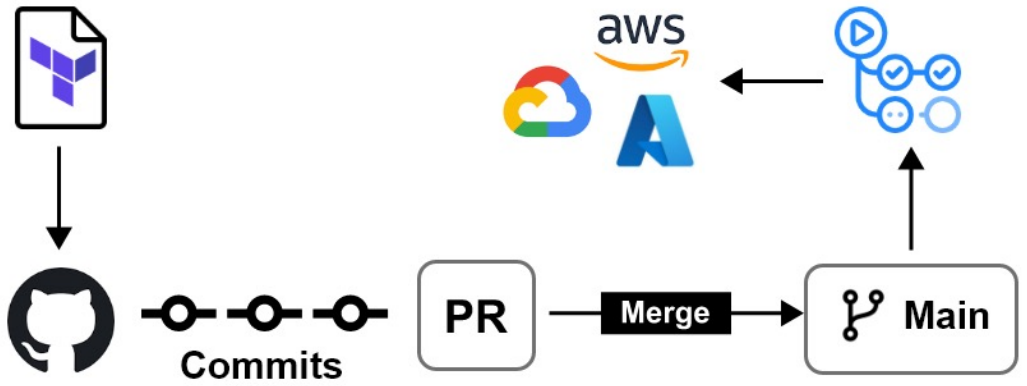
Packer

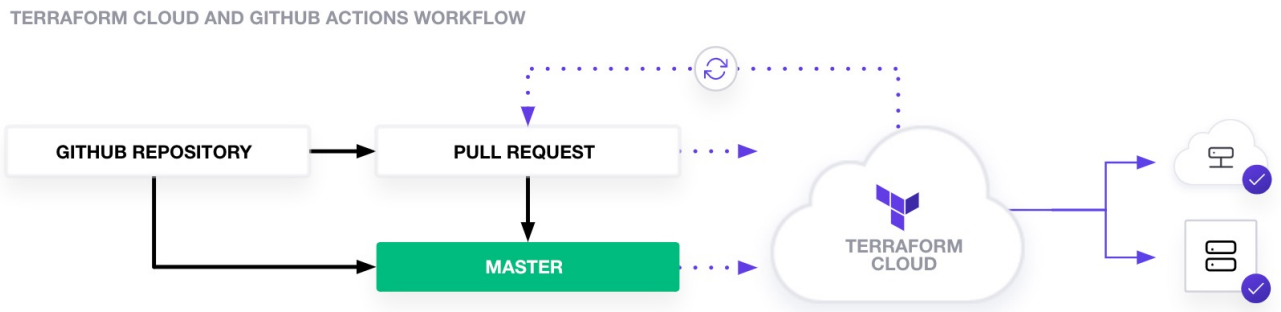
Golden Images

- Guarantee of 1-to-1 with your fleet
- Increased assurance of consistency, security
- Speeds up your deployments

What is GitOps?

GitOps is when you take Infrastructure as Code (IaC) and you use a git repository to **introduce a formal process to review and accept changes to infrastructure code**, once that code is accepted, it automatically triggers a deploy





HashiCorp

HashiCorp is a company specializing in managed **open-source tools** used to support the **development and deployment of large-scale service-oriented software installations**

What is HashiCorp Cloud Platform (HCP)?

HCP is a unified platform to access Hashicorp various products.

HCP services are **cloud agnostic**

- support for the main cloud service providers (CSPs)
  - eg. AWS, GCP and Azure
- highly suited for **multi-cloud** workloads

HashiCorp Products

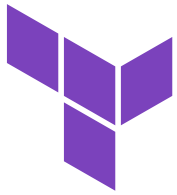
Boundary
secure remote access to systems based on trusted identity.

Consul
service discovery platform. provides a full-featured service mesh for secure service segmentation across any cloud or runtime environment, and distributed key-value storage for application configuration

Nomad
scheduling and deployment of tasks across worker nodes in a cluster

Packer
tool for building virtual-machine images for later deployment.

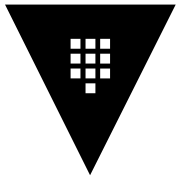
HashiCorp Products



Terraform
infrastructure as code software which enables provisioning and adapting virtual infrastructure across all major cloud provider

Terraform Cloud – a place to storage and manage IaC in the cloud or with teams

Vagrant
building and maintenance of reproducible software-development environments via virtualization technology



Vault
secrets management, identity-based access, encrypting application data and auditing of secrets for applications, systems, and users

Waypoint
modern workflow to build, deploy, and release across platforms

What is Terraform?

Terraform is an **open-source** and **cloud-agnostic** Infrastructure as Code (IaC) tool.

Terraform uses **declarative** configuration files.

The configuration files are written in **HashiCorp Configuration Language (HCL)**.

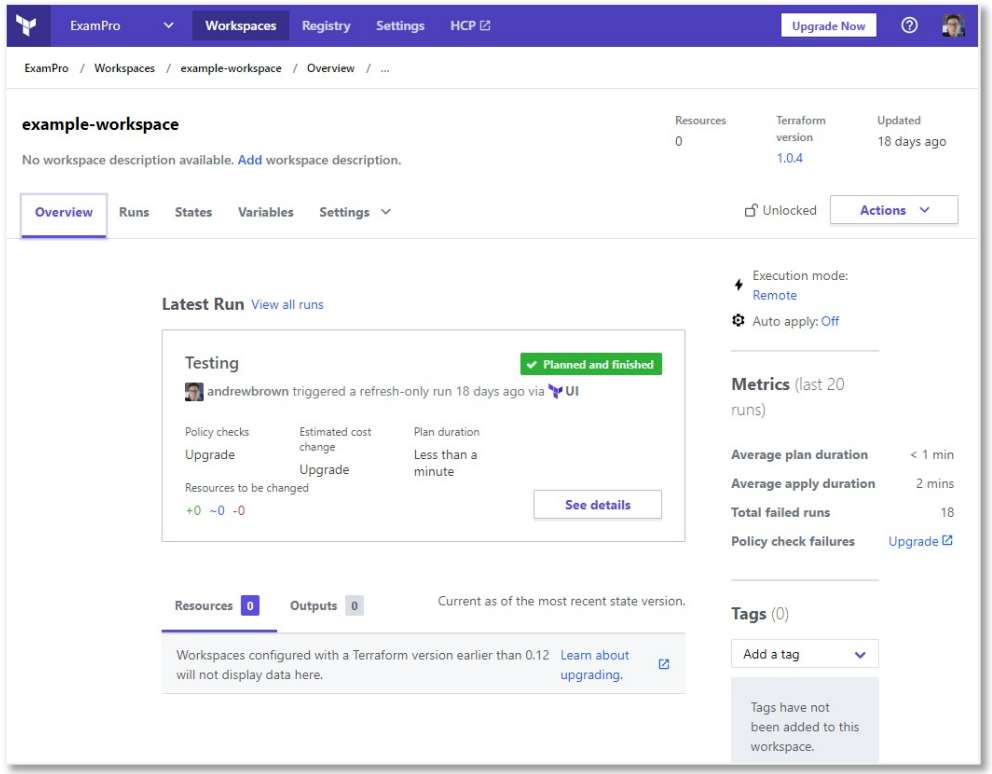
Notable features of Terraform:

- Installable modules
- Plan and predict changes
- Dependency graphing
- State management
- Provision infrastructure in familiar languages
  - via AWS CDK
- Terraform Registry with 1000+ providers

```
resource "aws_instance" "iac_in_action" {
  ami               = var.ami_id
  instance_type     = var.instance_type
  availability_zone = var.availability_zone

  // dynamically retrieve SSH Key Name
  key_name = aws_key_pair.iac_in_action.key_name

  // dynamically set Security Group ID (firewall)
  vpc_security_group_ids = [aws_security_group.iac_in_action.id]

  tags = {
    Name = "Terraform-managed EC2 Instance for IaC in Action"
  }
}
```

What is Terraform Cloud?

Terraform Cloud



Terraform Cloud is a Software as Service (SaaS) offering for:

- Remote state storage
- Version Control integrations
- Flexible workflows
- Collaborate on Infrastructure changes

in a single **unified web portal**.

www.terraform.io/cloud

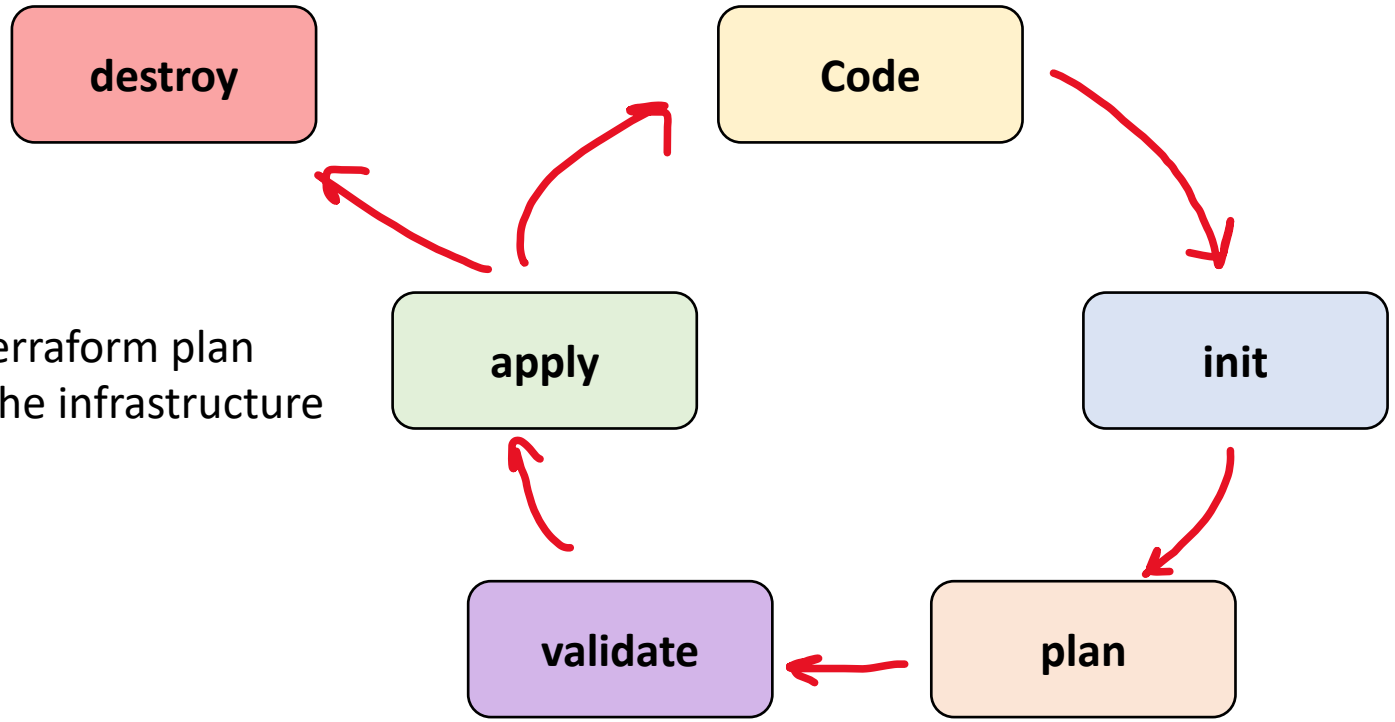
Terraform Cloud has a **generous free-tier** that allows for team collaboration for the first **5 users** of your organization

In majority of cases you should be using Terraform Cloud.

The only case where you may not want to use it to manage your state file is your company has many regulatory requirements along with a long procurement process so you could use Standard remote backend, Atlantis, or investigate Terraform Enterprise

The underlying software for Terraform Cloud and Terraform Enterprise is known as the “Terraform Platform”

Terraform Lifecycle



Destroy the remote infrastructure

Write or Update your Terraform configuration file

Execute the terraform plan provisioning the infrastructure

Initialize your project
Pull latest providers and modules

Ensure types and values are valid
Ensures required attributes are present

Speculate what will change
or Generate a saved execution plan

Terraform – Change Automation

What is Change Management?
A standard approach to apply change, and resolving conflicts brought about by change.
In the context of Infrastructure as Code (IaC), Change management is the procedure that will be followed when resources are modified and applied via configuration script.

What is Change Automation?
a way of **automatically** creating a consistent, systematic, and predictable way of managing change request via controls and policies

Terraform uses Change Automation in the form of **Execution Plans** and **Resources graphs** to apply and review complex **changesets**

What is a ChangeSet?
A collection of commits that represent changes made to a versioning repository. IaC uses ChangeSets so you can see what has changed by who over time.

Change Automation allows you to know exactly what Terraform will change and in what order, avoiding many possible human errors.

Terraform – Execution Plans

An **Execution Plan** is a **manual review** of what will **add, change or destroy** before you apply changes eg. terraform apply

resources and configuration settings will be listed.

It will indicate will be added, changed or destroyed if this plan is approved:

A user must approve changes by typing: **yes**

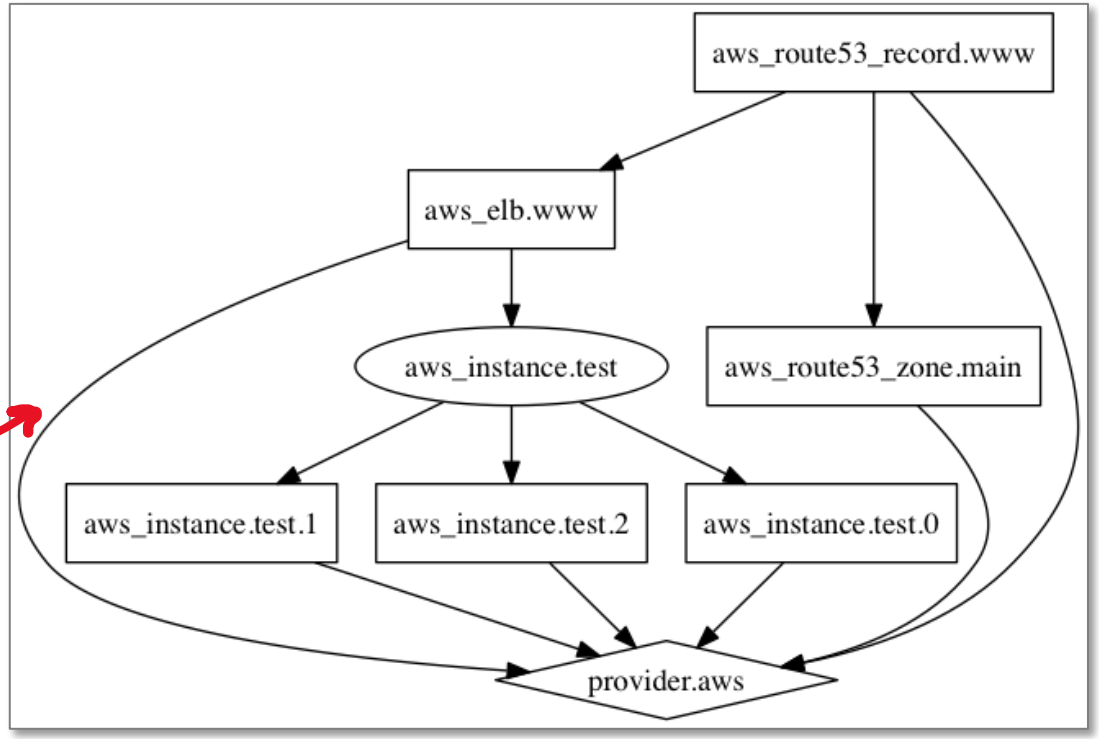
```
Terraform used the selected providers to generate the following execution
plan. Resource actions are indicated with the following symbols:
  + create

Terraform will perform the following actions:

  # aws_instance.app_server will be created
  + resource "aws_instance" "app_server" {
      + ami                                  = "ami-830c94e3"
      + arn                                  = (known after apply)
      + associate_public_ip_address          = (known after apply)
      + availability_zone                    = (known after apply)
      + cpu_core_count                       = (known after apply)
      + cpu_threads_per_core                 = (known after apply)
      + disable_api_termination              = (known after apply)
      + ebs_optimized                        = (known after apply)
      + get_password_data                    = false
  ...
Plan: 1 to add, 0 to change, 0 to destroy.

Do you want to perform these actions?
  Terraform will perform the actions described above.
  Only 'yes' will be accepted to approve.

  Enter a value: yes
```

Terraform – Visualizing Execution Plans

You can **visualize an execution plan** as a graph using the **terraform graph** command
Terraform will output a GraphViz file (you'll need GraphViz installed to view the file)

What is GraphViz?
open-source tools for drawing graphs specified in DOT language scripts having the file name extension "gv"

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

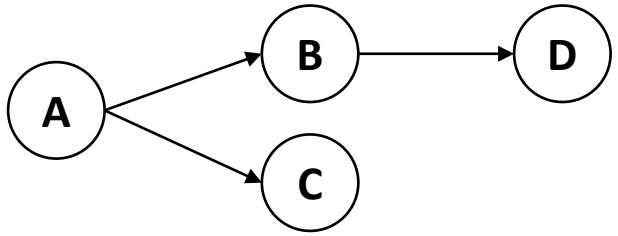


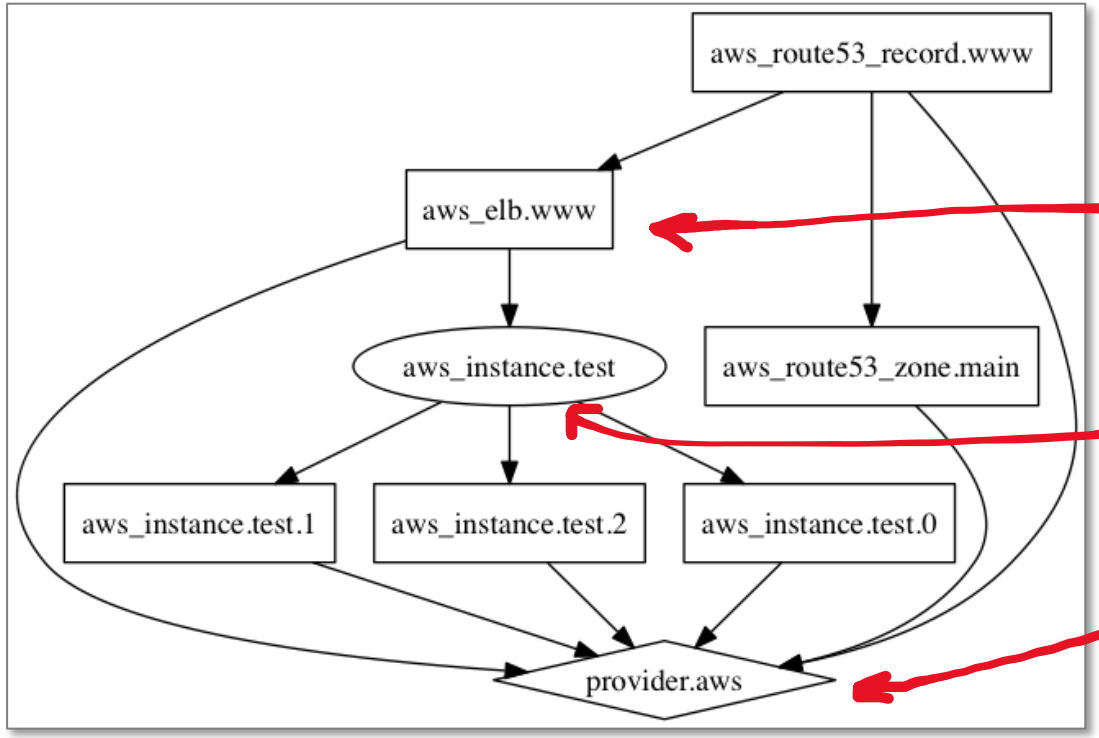
Terraform – Resource Graph

Terraform builds a **dependency graph** from the Terraform configurations, and walks this graph to generate plans, refresh state, and more.

When you use **terraform graph**, this is a **visual presentation** of the dependency graph

What is a dependency graph?
In mathematics is a directed graph representing dependencies of several objects towards each other





Resource Node
Represents a single resource

Resource Meta-Node
Represents a group of resources, but does not represent any action on its own

Provider Configuration Node
Represents the time to fully configure a provider

Terraform – Use Cases

IaC for Exotic Providers
Terraform supports a variety of providers outside of GCP, AWS, Azure and sometimes is the only provider. Terraform is open-source an extendable so any API could be used to create IaC tooling for any kind of cloud platform or technology. E.g. Heroku, Spotify Playlists.

Multi-Tier Applications – Terraform by default makes it easy to divide large and complex applications into isolate configuration scripts (module). It has a complexity advantage over cloud-native IaC tools for its flexibility while retaining simplicity over Imperative tools.

Disposable Environments – Easily stand up an environment for a software demo or a temporary development environment

Resource Schedulers – Terraform is not just defined to infrastructure of cloud resource but can be used to dynamic schedule Docker containers, Hadoop, Spark and other software tools. You can provision your own scheduling grid.

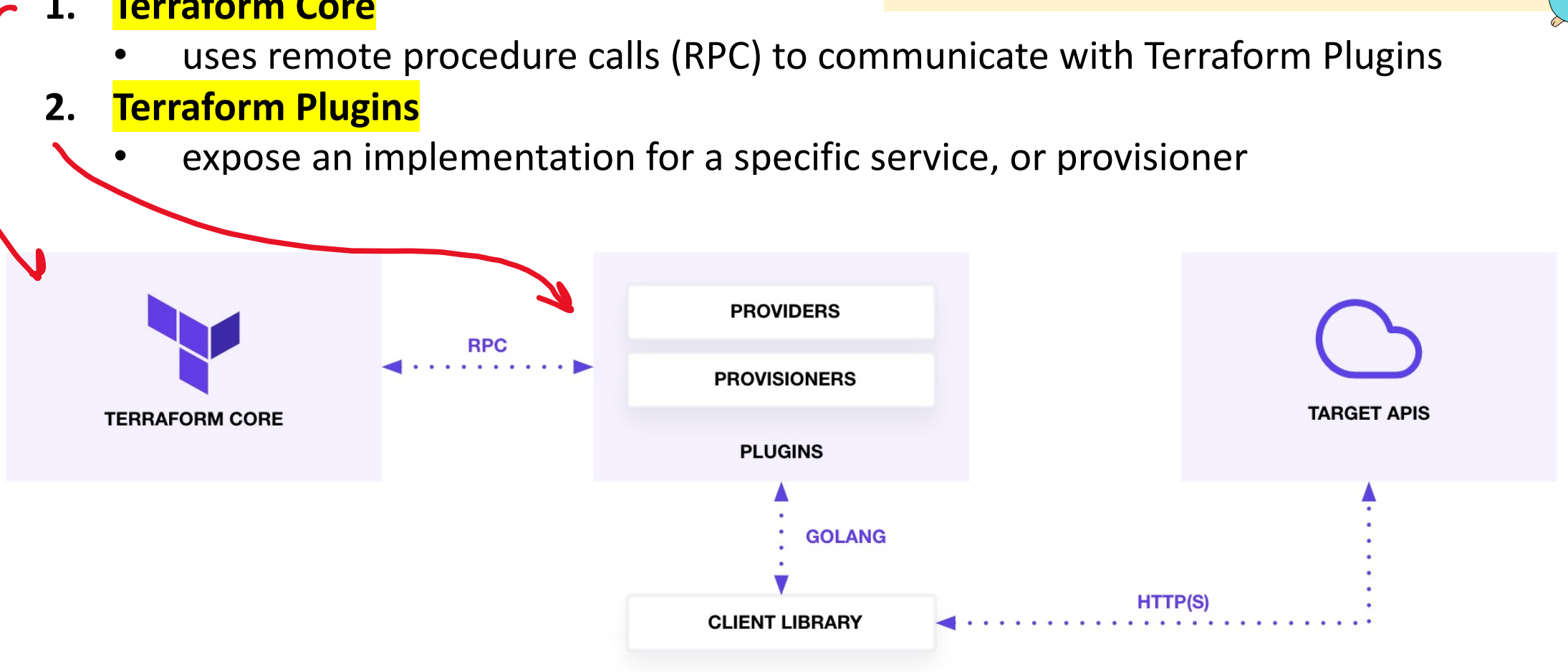
Multi-Cloud Deployment – Terraform is cloud-agnostic and allows a single configuration to be used to manage multiple providers, and to even handle cross-cloud dependencies.

Terraform Core and Terraform Plugins

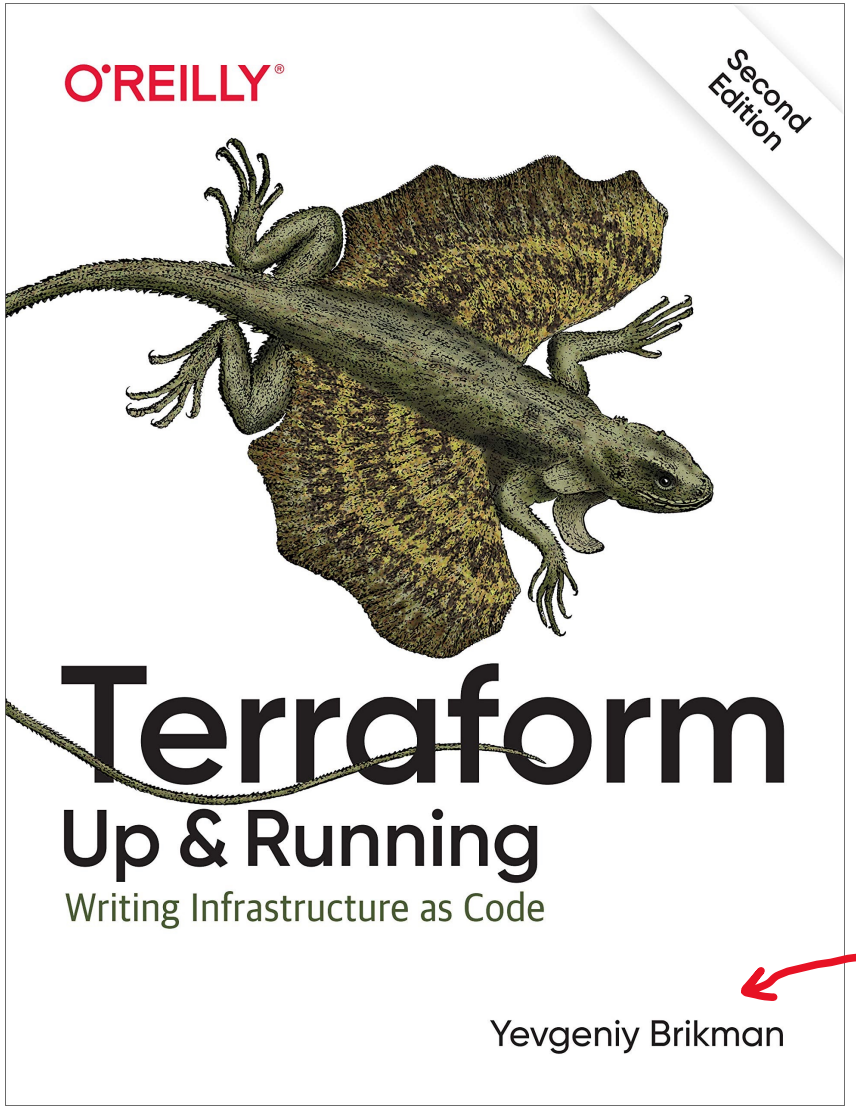
Terraform is logically split into two main parts:

1. **Terraform Core**
   - uses remote procedure calls (RPC) to communicate with Terraform Plugins
2. **Terraform Plugins**
   - expose an implementation for a specific service, or provisioner

Terraform Core is a statically-compiled **binary written in the Go programming language**.



Terraform Up and Running

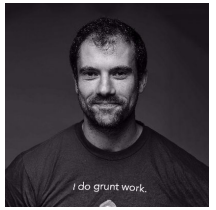


Terraform Up & Running takes a deep dive into the internal workings of Terraform.

If you want to go beyond this course for things like:

- Testing you Terraform Code
- Zero-Downtime Deployment
- Common Terraform Gotchas
- Composition of Production Grade Terraform Code

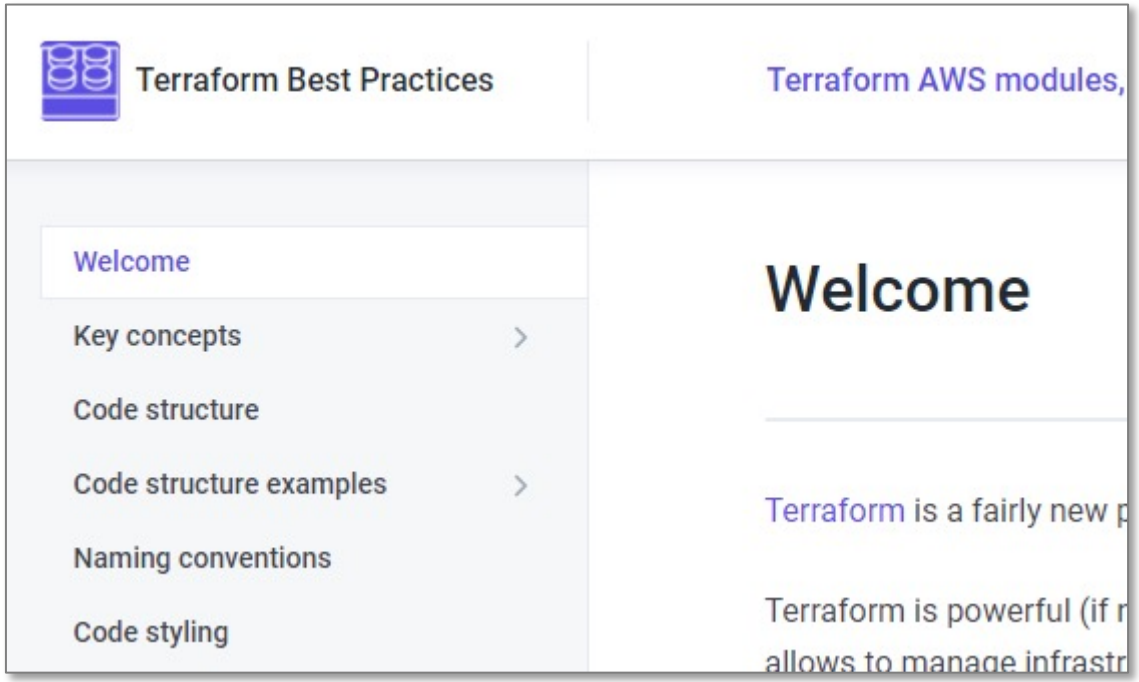
Yevgeniy ("Jim") Brikman is the co-founder of **Gruntwork**



Terraform Best Practices

Terraform is an **online open-book** about **Terraform Best Practices**

www.terraform-best-practices.com

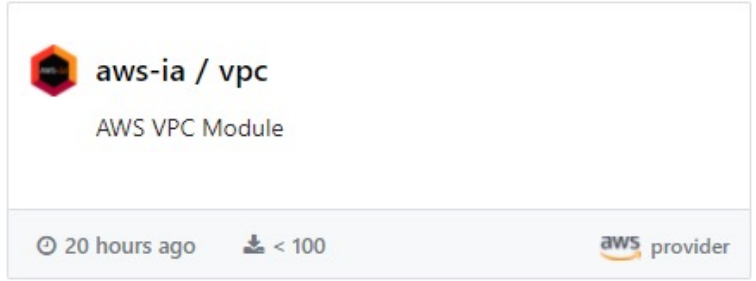


AWS-IA vs Terraform AWS Modules

AWS IA **Not Recommended**

Authored by AWS Integration and Automation team

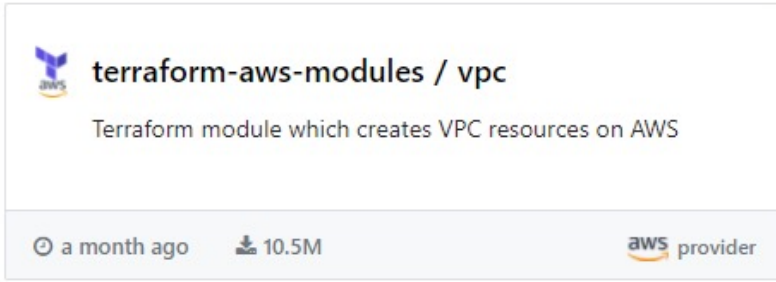
- They don't follow best practices for Terraform module development
- Very limited in functionality
- Very few libraries
- Are new, do not have much use



Terraform AWS Modules **Recommended**

Authored by Anton Babenko

- They follow best practices for Terraform Modules development
- Very flexible, covering many different use cases
- Many different libraries
- Have been around for **5 years**, heavily used (even previously by AWS)

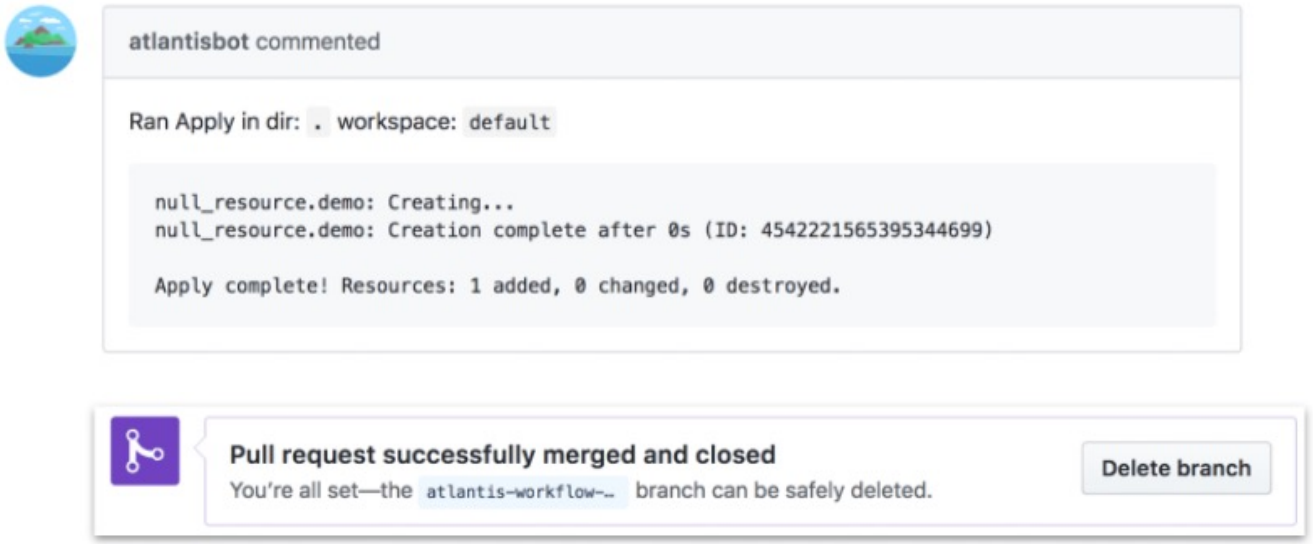


10M!

Atlantis

Atlantis is an open-source developer tool to **automate Terraform Pull Requests**

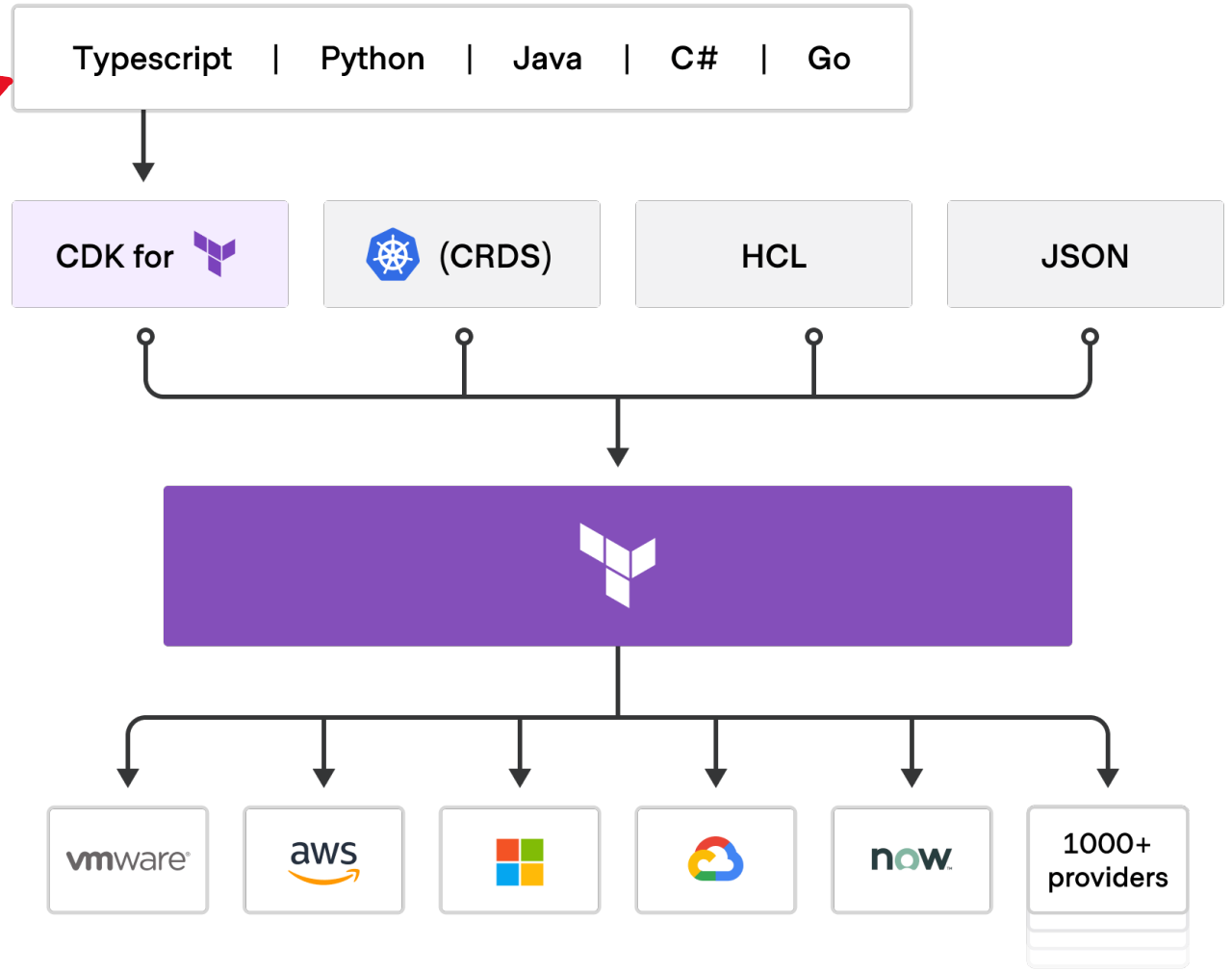
https://www.runatlantis.io



Atlantis was built as an alternative to Terraform Cloud automation.
The creators of Atantis now work at HashiCorp and is maintained by HashiCorp.

CDK for Terraform

AWS Cloud Development Kit (CDK) is an **imperative** Infrastructure as Code (IaC) tool With SDKs for your **favorite language**



AWS CDK is intended only for AWS cloud resources. CDK generates out CloudFormation (CFN) templates (known as synthesizing) and uses that for IaC.

CDK for Terraform is a standalone project by HashiCorp that allows you to use CDK, but instead of CFN templates it generates out Terraform templates.

This allows you **to use the CDK tooling to define IaC resources for any provider** available on Terraform via CDK.

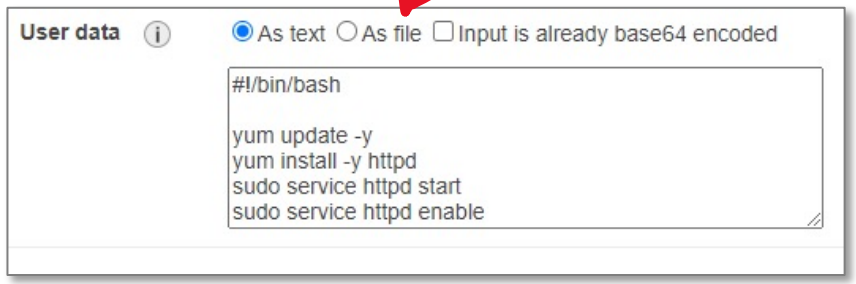
Terraform Provisioners

Terraform Provisioners install software, edit files, and provision machines created with Terraform

Terraform allows you to work with two different provisioners:

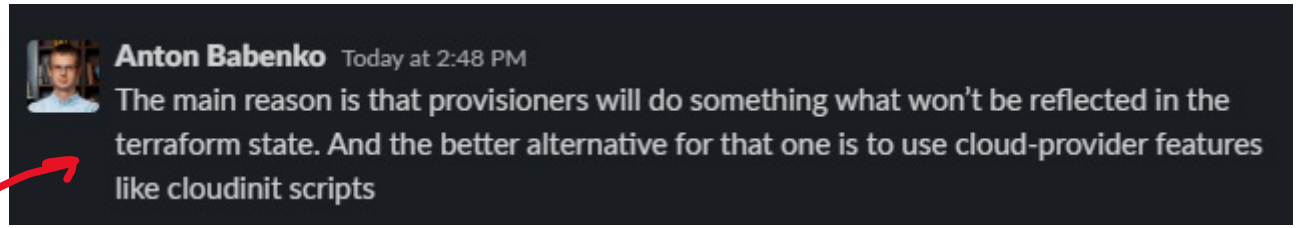
cloud-init

Cloud-Init is an industry standard for cross-platform cloud instance initializations. When you launch a VM on a Cloud Service Provider (CSP) you'll provide a YAML or Bash script.



Packer

Packer is an automated image-builder service. You provide a configuration file to create and provision the machine image and the image is the delivered to a repository for use.



Provisioners should only be used as a **last resort**. For most common situations there are better alternatives.

Terraform Provisioners

Create your own Cloud-Init script

```
users:
  - default
  - name: terraform
    gecos: terraform
    primary_group: hashicorp
    sudo: ALL=(ALL) NOPASSWD:ALL
    groups: users, admin
    ssh_import_id:
    lock_passwd: false
    ssh_authorized_keys:
      -  # Paste your created SSH key here
package_upgrade: yes
package_update: yes
packages:
  - httpd
runcmd:
  - sudo service httpd start
  - sudo service httpd enable
```

Define the template file

```
data "template_file" "user_data" {
  template = file("../scripts/add-ssh-web-app.yaml")
}

resource "aws_instance" "web" {
  ami                         = data.aws_ami.ubuntu.id
  instance_type               = "t2.micro"
  subnet_id                   = aws_subnet.subnet_public.id
  vpc_security_group_ids      = [aws_security_group.sg_22_80.id]
  associate_public_ip_address = true
  user_data                   = data.template_file.user_data.rendered

  tags = {
    Name = "Learn-CloudInit"
  }
}
```

Reference it in the userdata for the Virtual Machine

Terraform Provisioners

Terraform use to directly to support third-party Provisioning tools in the Terraform language Support was **deprecated** because Terraform considered using Provisioners to be poor practice suggesting better alternatives.

Cloud-Init supports Chef and Puppet, so you can just use Cloud-Init

```yaml
puppet:
  install: true
  version: "7.7.0"
  install_type: "packages"
  collection: "puppet7"
  cleanup: true
  aio_install_url:
"https://raw.githubusercontent.com/puppetlabs/install-
puppet/main/install.sh"
  conf_file: "/etc/puppet/puppet.conf"
  ssl_dir: "/var/lib/puppet/ssl"
  csr_attributes_path: "/etc/puppet/csr_attributes.yaml"
  package_name: "puppet"
  exec: false
  exec_args: ['--test']
  conf:
    agent:
      server: "puppetserver.example.org"
```

It is uncertain if this advice extends to Ansible. Terraform and Ansible has lots of learning materials on how their technologies complement each other.

Local-exec

Local-exec allows you to execute **local commands** *after* a resource is provisioned.

The machine that is executing Terraform *eg. terraform apply* is **where** the command will execute.

A local environment could be…..

Local Machine
Your laptop / workstation

Build Server
eg. GCP Cloud Build, AWS CodeBuild, Jenkins

Terraform Cloud Run Environment
single-use Linux virtual machine

Example Use Case
After you provision a VM you need to supply the Public IP to a third-party security service to add the VM IP address and you accomplish this by using locally installed third-party CLI on your build server.

Outputs vs Local-Exec
Terraform outputs allows you to output results after running Terraform apply

local exec allows you to run any arbitrary commands on your local machine. Commonly used to trigger Configuration Management eg. Ansible, Chef, Puppet

Local-exec

command (required)
The command you want to execute

working_dir
Where the command will be executed
eg. /user/andrew/home/project

interpreter
The entry point for the command.
What local program will run the command eg.
Bash, Ruby, AWS CLI, PowerShell

Environment
Key and value pair of environment variables

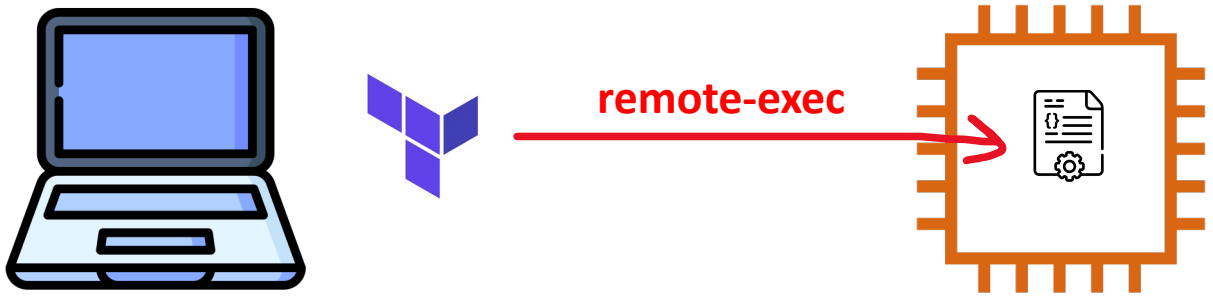
```
resource "aws_instance" "web" {
  # ...

  provisioner "local-exec" {
    command = "echo ${self.private_ip} >> private_ips.txt"
  }
}
```

```
resource "null_resource" "example2" {
  provisioner "local-exec" {
    command = "Get-Date > completed.txt"
    interpreter = ["PowerShell", "-Command"]
  }
}
```

```
resource "aws_instance" "web" {
  # ...

  provisioner "local-exec" {
    command = "echo $KEY $SECRET >> credentials.yml"

    environment = {
      KEY = "Jlmyn61Qmc8wiux9zprS9v4n"
      SECRET = "U32KIy2T1fW3xGDlFLggXjuN"
    }
  }
}
```

Remote-exec

Remote-exec allows you to execute **commands on a target resource** *after* a resource is provisioned.



Local Machine executing Terraform

Provisioned VM (resource) executing provided commands/script

Remote-Exec is useful for provisioning a Virtual Machine with a simple set of commands.

For more complex tasks its recommended to use Cloud-Init, and strongly recommended in all cases to bake Golden Images via Packer or EC2 Image Builder

Remote-exec

Remote Command has three different modes:

Inline - list of command strings

Script - relative or absolute local script that will be copied to the remote resource and then executed

Scripts - relative or absolute local scripts that will be copied to the remote resource and then executed and executed in order.

You can only choose to use one mode at a time

```
resource "aws_instance" "web" {
  # ...

  provisioner "remote-exec" {
    inline = [
      "puppet apply",
      "consul join ${aws_instance.web.private_ip}",
    ]
  }
}
```

```
resource "aws_instance" "web" {
  # ...

  provisioner "remote-exec" {
    scripts = [
      "./setup-users.sh",
      "/home/andrew/Desktop/bootstrap"
    ]
  }
}
```

File

file provisioner is used to copy files or directories from our local machine to the newly created resource

Source – the local file we want to upload to the remote machine

Content – a file or a folder

Destination – where you want to upload the file on the remote machine

You may require a connection block within the provisioner for authentication

```
resource "aws_instance" "web" {
  # ...

  # Copies the myapp.conf file to /etc/myapp.conf
  provisioner "file" {
    source      = "conf/myapp.conf"
    destination = "/etc/myapp.conf"
  }

  # Copies the string in content into /tmp/file.log
  provisioner "file" {
    content     = "ami used: ${self.ami}"
    destination = "/tmp/file.log"
  }

  # Copies the configs.d folder to /etc/configs.d
  provisioner "file" {
    source      = "conf/configs.d"
    destination = "/etc"
  }

  # Copies all files and folders in apps/app1 to
D:/IIS/webapp1
  provisioner "file" {
    source      = "apps/app1/"
    destination = "D:/IIS/webapp1"
  }
}
```

Connection

A connection block tells a **provisioner** or **resource** how to establish a connection

You can connect via **SSH**

With SSH you can connect through a Bastion Host eg:

- bastion_host
- bastion_host_key
- bastion_port
- bastion_user
- bastion_password
- bastion_private_key
- bastion_certificate

You can connect via **Windows Remote Management (winrm)**

```
# Copies the file as the root user using SSH
provisioner "file" {
  source      = "conf/myapp.conf"
  destination = "/etc/myapp.conf"

  connection {
    type     = "ssh"
    user     = "root"
    password = "${var.root_password}"
    host     = "${var.host}"
  }
}

# Copies the file as the Administrator user using
WinRM
provisioner "file" {
  source      = "conf/myapp.conf"
  destination = "C:/App/myapp.conf"

  connection {
    type     = "winrm"
    user     = "Administrator"
    password = "${var.admin_password}"
    host     = "${var.host}"
  }
}
```

Null Resources

null_resource is a placeholder for resources that have no specific association to a provider resources.

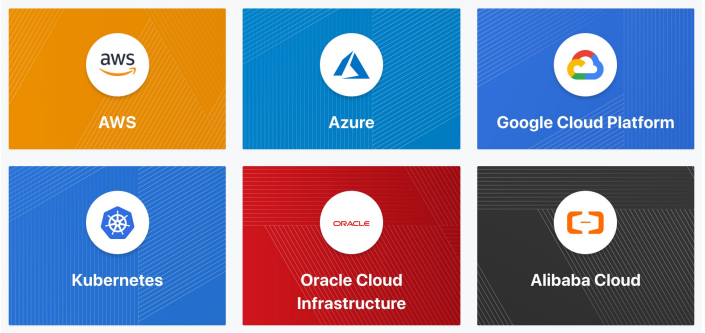
You can provide a **connection** an **triggers** to a resource

Triggers is a map of values which **should cause this set of provisioners to re-run**.

Values are meant to be interpolated references to variables or attributes of other resources

```
resource "aws_instance" "cluster" {
  count = 3

  # ...
}

resource "null_resource" "cluster" {
  # Changes to any instance of the cluster requires re-provisioning
  triggers = {
    cluster_instance_ids = "${join(",", aws_instance.cluster.*.id)}"
  }

  # Bootstrap script can run on any instance of the cluster
  # So we just choose the first in this case
  connection {
    host = "${element(aws_instance.cluster.*.public_ip, 0)}"
  }

  provisioner "remote-exec" {
    # Bootstrap script called with private_ip of each node in the cluster
    inline = [
      "bootstrap-cluster.sh ${join(" ", aws_instance.cluster.*.private_ip)}",
    ]
  }
}
```

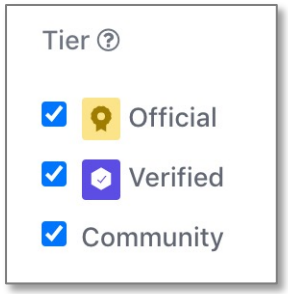
Terraform Providers



Providers are Terraform Plugins that allow you to interactive with:

- Cloud Service Providers (CSPs) eg. **AWS, Azure, GCP**
- Software as a Service (SaaS) Providers eg. **Github, Angolia, Stripe**
- Other APIs eg. **Kubernetes, Postgres**

Providers are required for your Terraform Configuration file to work.



Providers come in three tiers:

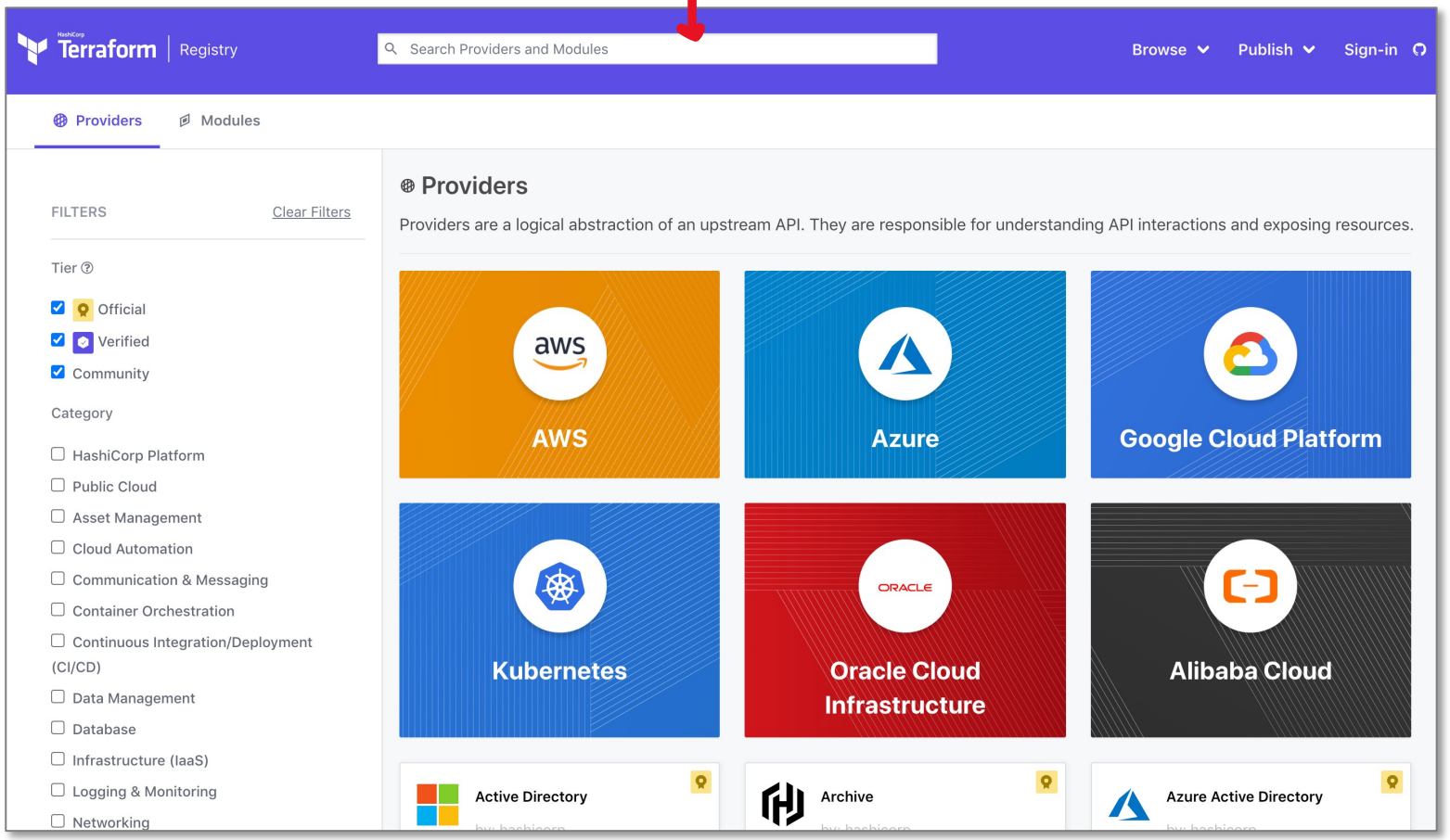
Official — Published by the company that owns the provider technology or service
Verified — actively maintained, up-to-date and compatible with both Terraform and Provider
Community — published by a community member but no guarantee of maintenance, up-to-date or compatibility

Providers are distributed separately from Terraform and the plugins must be downloaded before use.
terraform init will download the necessary provider plugins listed in a Terraform configuration file.

Terraform Registry

Terraform Registry is a **website portal** to **browse, download or publish** available **Providers** or **Modules**

https://registry.terraform.io



Provider

A provider is a plugin that is mapping to a Cloud Service Provider (CSPs) API.

Module

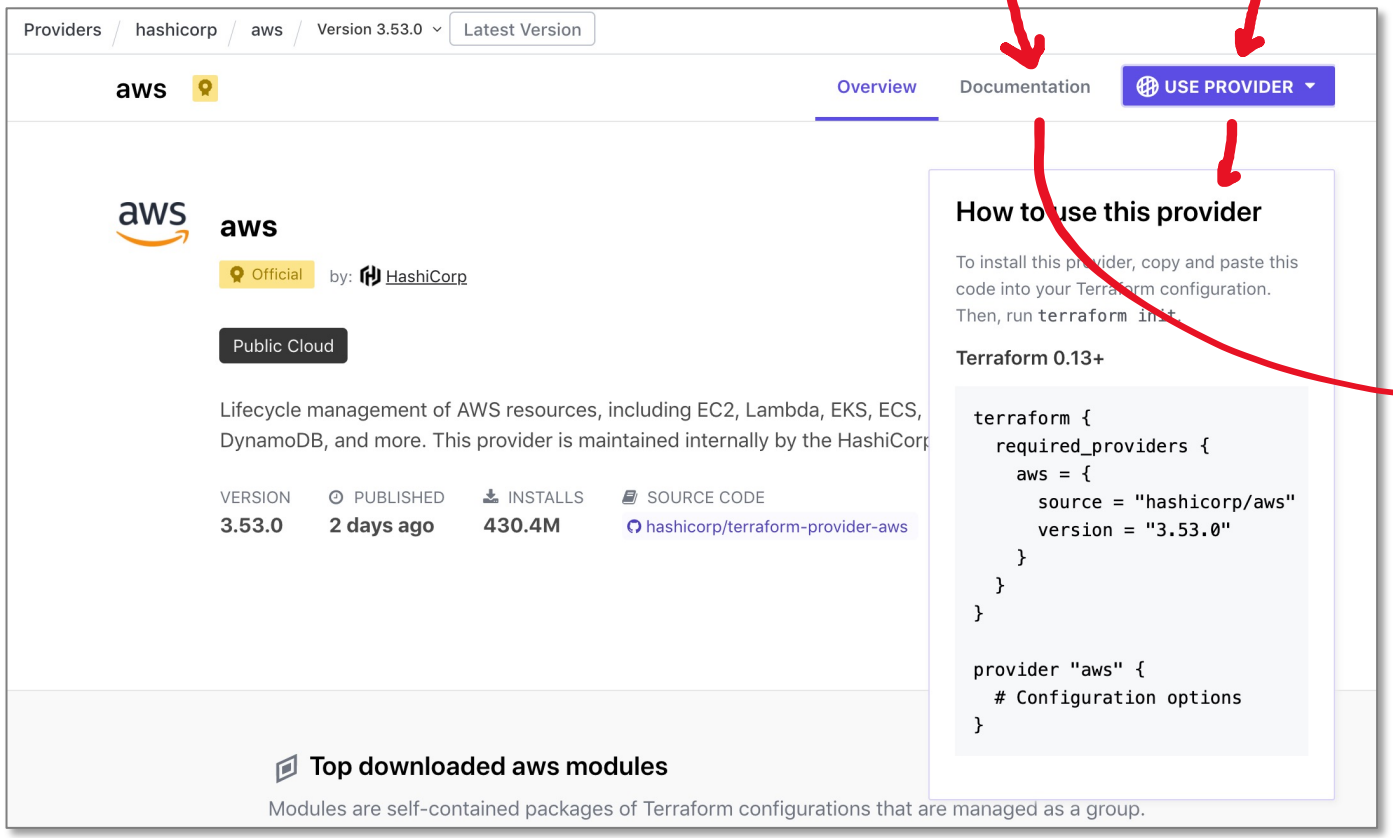
A module is a group of configuration files that provide common configuration functionality.

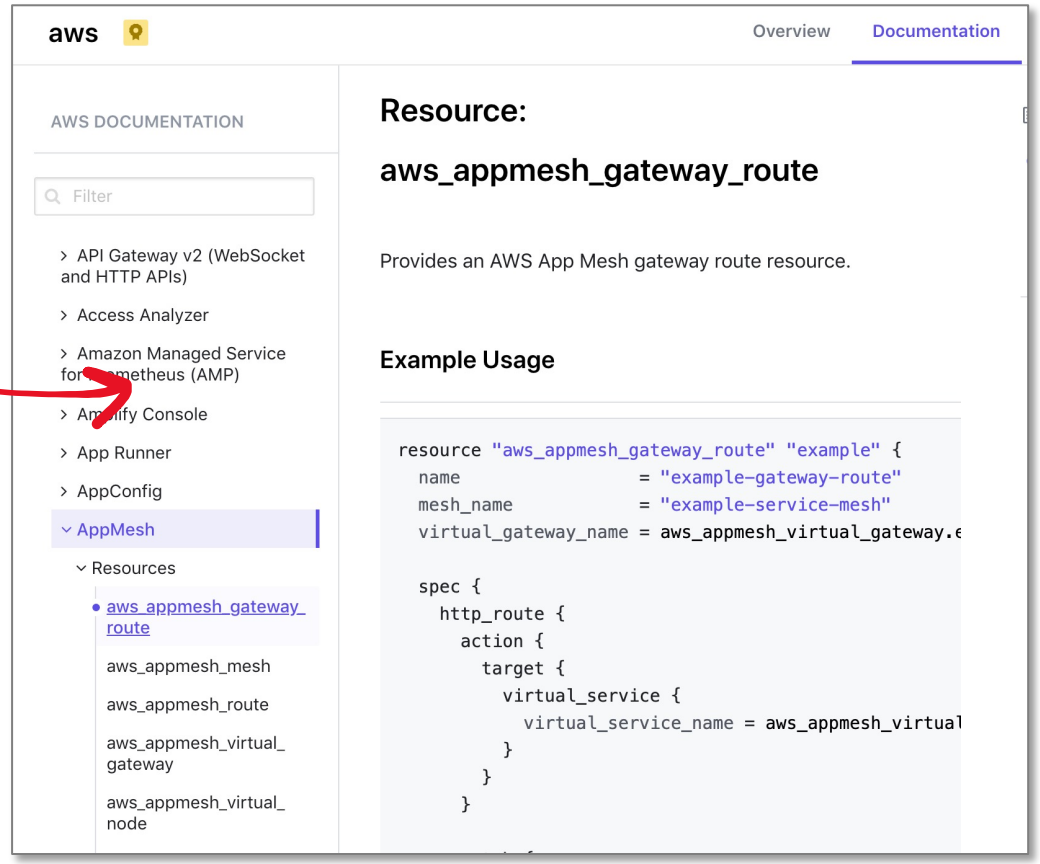
- Enforces best practices
- reduce the amount of code
- Reduce time to develop scripts

Everything published to Terraform Registry is **public-facing**

Terraform Registry – Providers

You can easily find **documentation** and **code sample** for providers



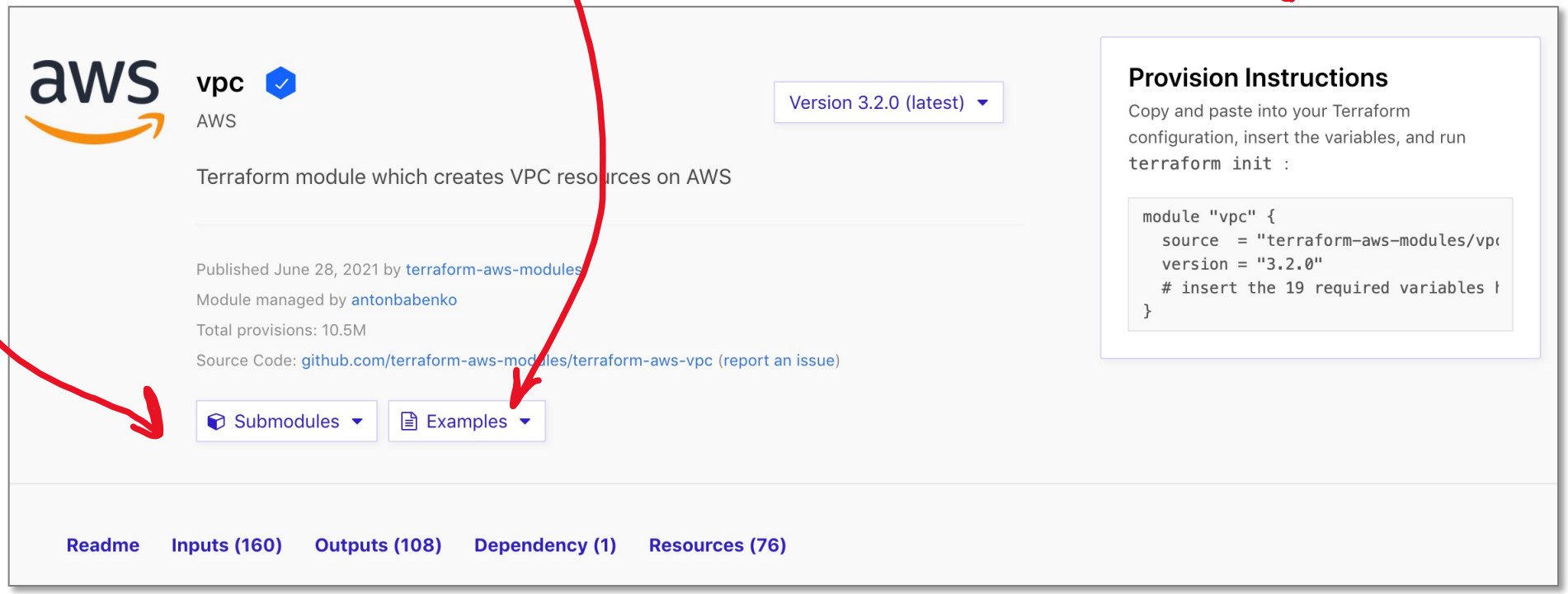


Terraform Registry

Lots of examples for common use cases

You can easily grab the **module code**:

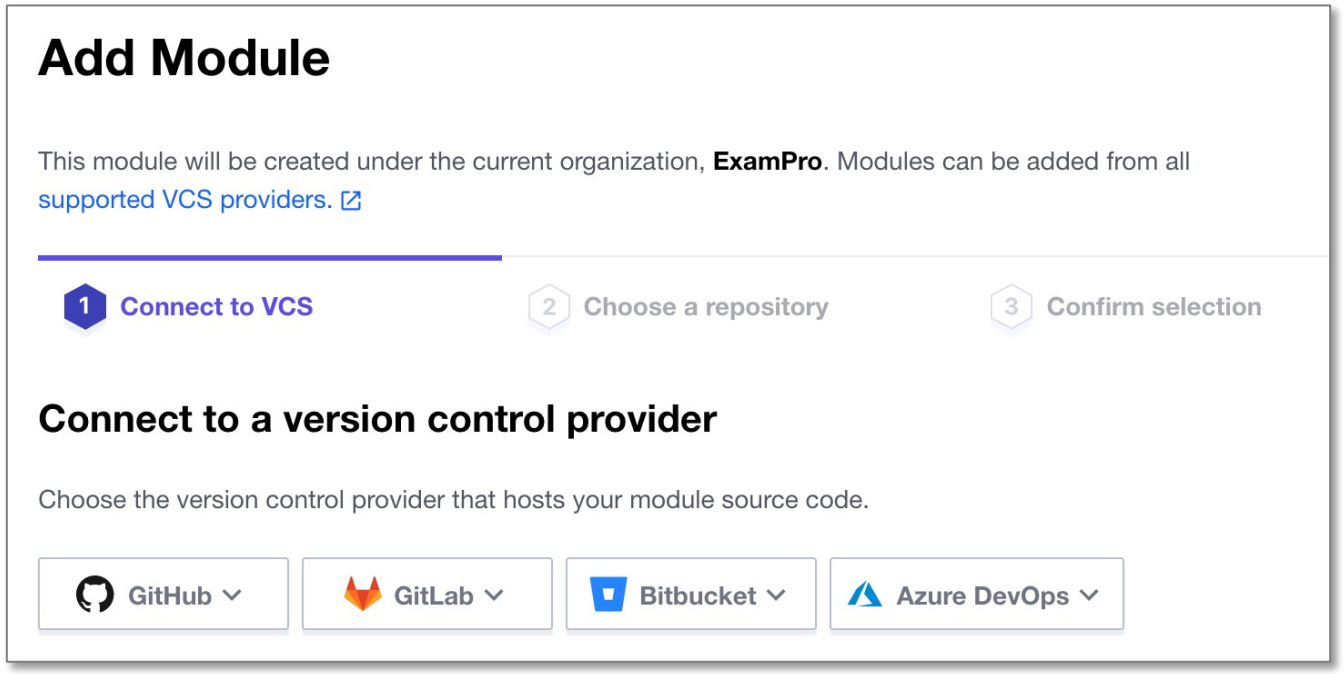
A list of dependent modules



Terraform Cloud – Private Registry

Terraform Cloud allows you to **publish private modules** for your Organization within the **Terraform Cloud Private Registry**

When creating a module you need to connect to a Version Control System (VCS) and choose a repository



Terraform Providers Command

Get a list of the current providers you are using

```
terraform providers
Providers required by configuration:
.
├── provider[registry.terraform.io/hashicorp/azurerm] 2.72.0
├── provider[registry.terraform.io/hashicorp/google] 3.80.0
├── provider[registry.terraform.io/hashicorp/aws] 3.54.0
├── module.network
│   └── provider[registry.terraform.io/hashicorp/azurerm]
└── module.linuxservers
    ├── provider[registry.terraform.io/hashicorp/azurerm]
    ├── provider[registry.terraform.io/hashicorp/random]
    └── module.os
```

Terraform Provider Configuration

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

Set an alternative provider

How to reference an alias provider

```
resource "aws_instance" "foo" {
  provider = aws.west
  # ...
}
```

How to set alias provider for a parent module

```
terraform {
  required_providers {
    mycloud = {
      source  = "mycorp/mycloud"
      version = "~> 1.0"
      configuration_aliases = [ mycloud.alternate ]
    }
  }}
```

How to set alias provider for a child module

```
module "aws_vpc" {
  source = "./aws_vpc"
  providers = {
    aws = aws.west
  }
}
```

Terraform Modules

A Terraform module is a group of configuration files that provide common configuration functionality.

- Enforces best practices
- reduce the amount of code
- Reduce time to develop scripts

AWS Provider (not a module)

If you had to create a VPC you would have specific many networking resources.

```
resource "aws_vpc" "main" {
  cidr_block       = "10.0.0.0/16"
  instance_tenancy = "default"

  tags = {
    Name = "main"
  }
}

resource "aws_subnet" "main" {
  vpc_id     = aws_vpc.main.id
  cidr_block = "10.0.1.0/24"

  tags = {
    Name = "Main"
  }
}

# ....
```

AWS VPC Module

Using a module you can use a a shorthand Domain Specific Language (DSL) That will reduce the amount of work.

```
module "vpc" {
  source = "terraform-aws-modules/vpc/aws"

  name = "my-vpc"
  cidr = "10.0.0.0/16"

  azs             = ["eu-west-1a", "eu-west-1b", "eu-west-1c"]
  private_subnets = ["10.0.1.0/24", "10.0.2.0/24", "10.0.3.0/24"]
  public_subnets  = ["10.0.101.0/24", "10.0.102.0/24", "10.0.103.0/24"]

  enable_nat_gateway = true
  enable_vpn_gateway = true

  tags = {
    Terraform = "true"
    Environment = "dev"
  }
```

Modules: Imagine clicking a wizard that creates many cloud resources e.g. VPC Wizard

Terraform Modules

Azure VM via the **Azure Provider**

Azure VM via a **Compute and Network Module**

```
resource "azurerm_resource_group" "example" {
  name     = "example-resources"
  location = "West Europe"
}

module "linuxservers" {
  source              = "Azure/compute/azurerm"
  resource_group_name = azurerm_resource_group.example.name
  vm_os_simple        = "UbuntuServer"
  public_ip_dns       = ["linsimplevmips"]
  vnet_subnet_id      = module.network.vnet_subnets[0]

  depends_on = [azurerm_resource_group.example]
}

module "network" {
  source              = "Azure/network/azurerm"
  resource_group_name = azurerm_resource_group.example.name
  subnet_prefixes     = ["10.0.1.0/24"]
  subnet_names        = ["subnet1"]

  depends_on = [azurerm_resource_group.example]
}

output "linux_vm_public_name" {
  value = module.linuxservers.public_ip_dns_name
}
```

Terraform Providers – The Fine Line

The Fine Line is understanding **the granularities of responsibility** between Terraform Infrastructure as Code and Third-Party Configuration Management.

When you have a Postgres Database which is a typical resource compared to a cloud service like an Amazon S3
Who should automate what?

A Terraform Provisioner could be using Ansible

Terraform

providers	modules	provisioners
Create a Postgres Databases	**Create a Postgres User**	**Stage Seed Data**

Entities. If you want governance or asset resource management

A task done one time to setup the database

Ansible (Third Party Configuration Management Tool)

- **Backup tables to Datawarehouse**
- **Truncate daily tables**

Repeatable tasks for on-going maintenance

Terraform Language

Terraform files contain the configuration information about **providers** and **resources**.

Terraform files end in the extension of **.tf** or either **.tf.json**
Terraform files are written in the **Terraform Language** and is the extension of HCL

Terraform language consists of only a few basic elements:

- **Blocks —** containers for other content, represent an object
  - block type — can have zero or more labels and a body
  - block label — name of a block
- **Arguments —** assign a value to a name
  - They appear within blocks
- **Expressions —** represent a value, either literally or by referencing and combining other values
  - They appear as values for arguments, or within other expressions.

```
resource "aws_vpc" "main" {
  cidr_block = var.base_cidr_block
}

<BLOCK TYPE> "<BLOCK LABEL>" "<BLOCK LABEL>" {
  # Block body
  <IDENTIFIER> = <EXPRESSION> # Argument
}
```

You might come across HashiCorp Configuration Language (HCL) this is the low-level language for both the Terraform Language and alternative JSON syntax

Hashicorp Configuration Files – Syntax

Arguments

An *argument* assigns a value to a particular name

- arguments appear within blocks

```
image_id = "abc123"
```

Blocks

A block is a container for other content

```
resource "aws_instance" "example"
{
  ami = "abc123"

  network_interface {
    # ...
  }
}
```

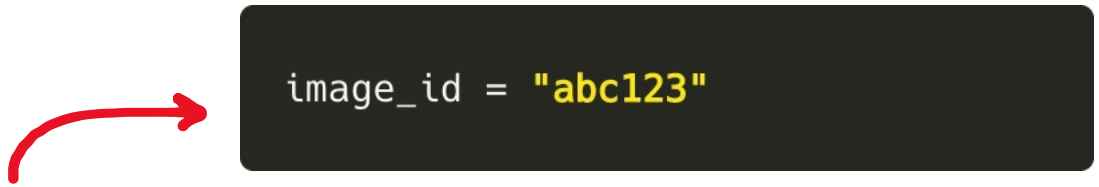
Block has a type **"resource"** and it expects two Block Labels

A block can contain **nested** blocks

different types have different number of required labels.

The brackets { } indicate the block **body**

Hashicorp Configuration Files – Syntax



Identifiers, uniquely identify objects of constructs in a Terraform Language:

- Argument names
- Block type names
- names Terraform-specific constructs eg. resources, input variables

Identifiers can contain:

- letters eg. abc
- digits eg. 012
- underscores eg. _
- hyphens eg. -

The first letter of an Identifiers cannot be a digit

Hashicorp Configuration Files – Syntax

Terraform language supports **3 different syntaxes** for comments

```
#  this is also a single line comment
```

```
// this is a single line comment
```

```
/*
This
is a
multiple comment
*/
```

This is the default comment style.
Formatting tools may transform // to #
eg. terraform fmt

Terraform configuration files must always be **UTF-8 encoded**
Terraform accepts configuration files with either Unix-style line endings (LF) or Windows-style line endings (CR + LF)

Hashicorp Configuration Files – Alternate JSON Syntax

Terraform also supports an *alternative syntax* that is JSON-compatible
Terraform expects JSON syntax files to be named with **.tf.json**

This syntax is useful when generating portions of a configuration programmatically, since existing JSON libraries can be used to prepare the generated configuration files.

Example of **JSON syntax**

```
{
  "resource": {
    "aws_instance": {
      "example": {
        "instance_type": "t2.micro",
        "ami": "ami-abc123"
      }
    }
  }
}
```

Terraform Settings

The special **terraform configuration block type** eg. **terraform { … }**
is used to configure some behaviors of Terraform itself

In Terraform settings we can specify:

- **required_version**
  - The expected version of terraform
- **required_providers**
  - The providers that will be pull during an terraform init
- **experiments**
  - Experimental language features, that the community can try and provide feedback
- **provider_meta**
  - module-specific information for providers

```
terraform {
  required_providers {
    aws = {
      version = ">= 2.7.0"
      source = "hashicorp/aws"
    }
  }
}
```

HashiCorp Configuration Language

HCL is an open-source toolkit for creating **structured configuration languages** that are both human and machine friendly, for use with command-line tools

github.com/hashicorp/hcl

HashiCorp Configuration Language (HCL)

- Terraform Language (.tf)
- Packer Template (.pkr.hcl)
- Vault Policies (no extension)
- Boundary Controllers and Workers (.hcl)
- Consul Configuration (.hcl)
- Waypoint Application Configuration(.hcl)
- Nomad Job Specifications (.nomad)
- Shipyard Blueprint (.hcl)
- Sentinel Policies ✗

eg. Dynamic Blocks, For Each…

Doesn't use HCL but its own ACL custom language

Input Variables

Input variables (aka variables or Terraform Variables)
are **parameters** for Terraform modules

Variables are defined
via **variable blocks.**

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

variable "availability_zone_names" {
  type    = list(string)
  default = ["us-west-1a"]
}

variable "docker_ports" {
  type = list(object({
    internal = number
    external = number
    protocol = string
  }))
  default = [
    {
      internal = 8300
      external = 8300
      protocol = "tcp"
    }
  ]
}
```

You can declare variables in either:

- The root module
- The child modules

Default	A default value which then makes the variable optional
type	This argument specifies what value types are accepted for the variable
Description	This specifies the input variable's documentation
Validation	A block to define validation rules, usually in addition to type constraints
Sensitive	Limits Terraform UI output when the variable is used in configuration

Variable Definitions Files

A variable definitions file allows you to set the values for multiple variables at once.
Variable definition files are named .tfvars or tfvars.json

By default **terraform.tfvars** will be autoloaded when included in the root of your project directory

```
image_id = "ami-abc123"
availability_zone_names = [
  "us-east-1a",
  "us-west-1c",
]
```

Variable Definition Files use the Terraform Language.

Variables via Environment Variables

A variable value can be defined by Environment Variables

Variable starting with **TF_VAR_**<name> will be read and loaded

```
export TF_VAR_image_id=ami-abc123
```

Loading Input Variables

Default Autoloaded Variables file
terraform.tfvars

When you create a named **terraform.tfvars** file it will be automatically loaded when running terraform apply

Additional Variables Files (not autoloaded)
my_variables.tfvars

You can create additional variables files eg. dev.tfvars, prod.tfvars
They will not be autoloaded (you'll need to specific them in via command line)

Additional Variables Files (autoloaded)
my_variables.**auto.**tfvars

If you name your file with auto.tfvars it will always be loaded

Specify a Variables file via Command Line
-var-file dev.tfvars

You can specific variables inline via the command line for individual overrides

Inline Variables via Command Line
-var ec2_type="t2.medium"

You can specific variables inline via the command line for individual overrides

Environment Variables
TF_VAR_my_variable_name

Terraform will watch for environment variables that begin with TF_VAR_ and apply those as variables

Variable Definition Precedence

You can override variables via many files and commands
The definition precedence is the order in which Terraform will read variables and as it goes down the list it will override variable.

- Environment Variables
- terraform.tfvars
- terraform.tfvars.json
- *.auto.tfvars or *.auto.tfvars.json
- -var and -var-file

Output Values

Output Values are computed values after a Terraform apply is performed.
Outputs allows you:

- to obtain information after resource provisioning e.g. public IP address
- output a file of values for programmatic integration
- Cross-reference stacks via outputs in a state file via terraform_remote_state

You can optionally provide a description

You can mark the output as sensitive so it does not show in output of your Terminal

```
output "db_password" {
  value       = aws_db_instance.db.password
  description = "The password for logging in to the database."
  sensitive   = true
}
```

Sensitive outputs will still be visible within the statefile.

Output Values

To print all the outputs for a statefile use the **terraform outputs**

```
$ terraform output
lb_url = "http://lb-5YI-project-alpha-dev-2144336064.us-east-1.elb.amazonaws.com/"
vpc_id = "vpc-004c2d1ba7394b3d6"
web_server_count = 4
```

Print a specific output with **terraform outputs <name>**

```
$ terraform output lb_url
"http://lb-5YI-project-alpha-dev-2144336064.us-east-1.elb.amazonaws.com/"
```

Use the **–json** flag to get output as json data.

```
$ terraform output -json
{
  "db_password": {
    "sensitive": true,
    "type": "string",
    "value": "notasecurepassword"
  },
```

Use the **–raw** flag to preserve quotes for strings

```
$ curl $(terraform output -raw lb_url)
<html><body><div>Hello, world!</div></body></html>
```

Local Values

A local value (locals) **assigns a name to an expression**, so you can **use it multiple times within a module** without repeating it.

Static value

computed values

Locals are set using the **locals block**

You can defined **multiple** locals blocks

You can **reference locals within locals**

```
locals {
  service_name = "forum"
  owner        = "Community Team"
}

locals {
  # Ids for multiple sets of EC2 instances, merged together
  instance_ids = concat(aws_instance.blue.*.id, aws_instance.green.*.id)
}

locals {
  # Common tags to be assigned to all resources
  common_tags = {
    Service = local.service_name
    Owner   = local.owner
  }
}
```

Local Values

Once a local value is declared, you can reference it in expressions as **local.<NAME>.**

```
resource "aws_instance" "example" {
  # ...

  tags = local.common_tags
}
```

When you referencing **you use the singular "local"**

Locals help can help DRY up your code.
It is best practice to **use locals sparingly** since it Terraform is intended to be declarative and overuse of locals can make it difficult to determine what the code is doing.

Data Sources

Data sources allow Terraform **use information defined outside of Terraform**, defined by another separate Terraform configuration, or modified by functions.

You specific what kind of external resource you want to select

You use filters to narrow down the selection

```
data "aws_ami" "web" {
  filter {
    name   = "state"
    values = ["available"]
  }

  filter {
    name   = "tag:Component"
    values = ["web"]
  }

  most_recent = true
}
```

```
resource "aws_instance" "web" {
  ami           = data.aws_ami.web.id
  instance_type = "t1.micro"
}
```

You use **data.** to reference data sources

References to Named Values

Named Values are **built-in expressions** to **reference various values** such as:

Resources	<Resource Type>.<Name> e.g. aws_instance.my_server
Input variables	**var**.<Name>
Local values	**local**.<Name>
Child module outputs	**module**.<Name>
Data sources	**data**.<Data Type>.<Name>

Filesystem and workspace info

- path.module - path of the module where the expression is placed
- path.root - path of the root module of the configuration
- path.cwd - path of the current working directory
- terraform.workspace – name of the currently selected workspace

Block-local values (within the body of blocks)

- count.**index** (when you use the count meta argument)
- each.**key** / each.**value** (when you use the for_each meta argument)
- **self**.<attribute> - self reference information within the block (provisioners and connections)

Named values resemble the attribute notation for map (object) values but are not objects and do not act as objects. You cannot use square brackets to access attribute of Named Values like an object.

Resource Meta Arguments

Terraform language defines several meta-arguments, which can be used with any **resource type** **to change the behavior of resources**.

- **depends_on**, for specifying explict dependencies
- **count**, for creating multiple resource instances according to a count
- **for_each**, to create multiple instances according to a map, or set of strings
- **provider**, for selecting a non-default provider configuration
- **lifecycle**, for lifecycle customizations
- **provisioner** and connection, for taking extra actions after resource creation

depends_on

The order of which resources are provisioned is important when resources depend on others before they are provisioned.

Terraform implicitly can determine the order of provision for resources but there may be some cases where it cannot determine the correct order.

depends_on allows you to explicitly specific a dependency of a resource.

```
resource "aws_iam_role_policy" "example" {
  name   = "example"
  role   = aws_iam_role.example.name
  # ...
}

resource "aws_instance" "example" {
  ami           = "ami-a1b2c3d4"
  instance_type = "t2.micro"
  iam_instance_profile = aws_iam_instance_profile.example
  depends_on = [
    aws_iam_role_policy.example,
  ]
}
```

count

When you are managing a pool of objects eg. a fleet of Virtual Machines you can use **count**.

Specify the **amount** of instances you want

```
resource "aws_instance" "server" {
  count = 4 # create four similar EC2 instances

  ami           = "ami-a1b2c3d4"
  instance_type = "t2.micro"

  tags = {
    Name = "Server ${count.index}"
  }
}
```

Get the current count **value** (index) via **count.index**

This value starts at 0

Count can accept **numeric expressions**:

- Must be whole number
- Number must be known before configuration

```
resource "aws_instance" "server" {
  # Create one instance for each subnet
  count = length(var.subnet_ids)
  # ....
```

for_each

for_each is similar to count for managing multiple related objects.
But you can iterate over a map for more dynamic values.

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

With a map:
each.key – print out the current key
each.value – print out the current value

```
resource "aws_iam_user" "the-accounts" {
  for_each = toset( ["Todd", "James", "Alice", "Dottie"] )
  name     = each.key
}
```

With a list:
each.key – print out the current key

Resource Behaviour

When you execute an execution order via Terraform Apply it will perform one of the following to a resource:

Create

- resources that exist in the configuration but are not associated with a real infrastructure object in the state.

Destroy

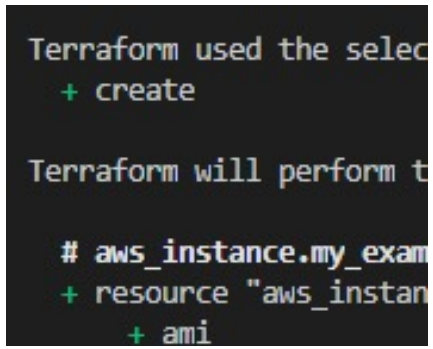
- resources that exist in the state but no longer exist in the configuration.

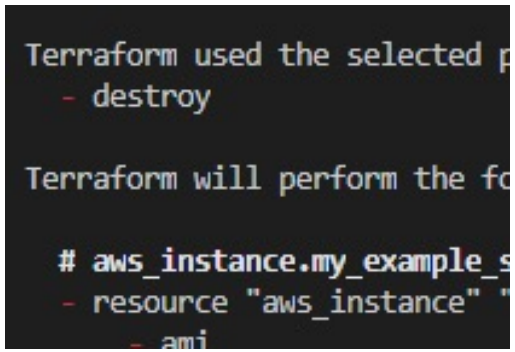
Update in-place

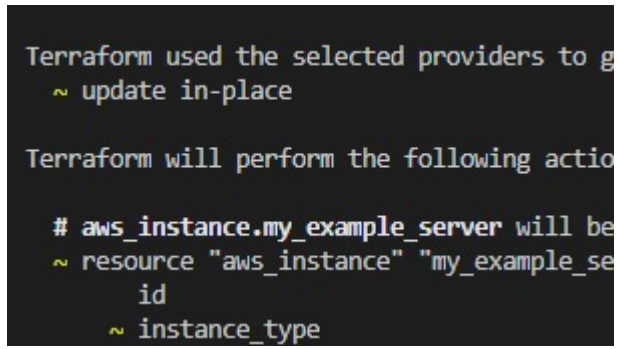
- resources whose arguments have changed.

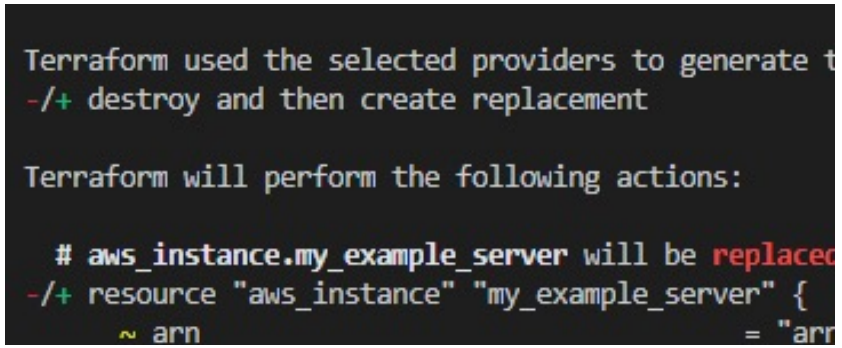
Destroy and re-create

- resources whose arguments have changed but which cannot be updated in-place due to remote API limitations.









lifecycle

Lifecycle block allows you to change what happens to resource e.g. create, update, destroy.
Lifecycle blocks are nested within resources

create_before_destroy (bool)
When replacing a resource first create the new resource before deleting it (the default is destroy old first)

prevent_destroy (bool)
Ensures a resource is not destroyed

ignore_changes (list of attributes)
Don't change the resource (create, update, destroy) the resource if a change occurs for the listed attributes.

```
resource "azurerm_resource_group" "example" {
  # ...

  lifecycle {
    create_before_destroy = true
  }
}
```

Resource Providers and Alias

If you need to override the default provider for a resource you can create alternative provider with **alias**

You reference the alias under in the attribute **provider** for a resource.

```
# default configuration
provider "google" {
  region = "us-central1"
}

# alternate configuration, whose alias is "europe"
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

  # ...
}
```

Introduction to Terraform Expressions

Expressions are used to **refer to** or **compute values** within a configuration.

Terraform Expressions is a large topic, and we'll be covering:

- Types and Values
- Strings and Templates
- References to Values
- Operators
- Function Calls
- Conditional Expressions
- For Expressions
- Splat Expressions
- Dynamic Blocks
- Type Constraints
- Version Constraints

Types and Values

The result of an expression is a **value**. All values have a **type**

primitive types

string

```
ami = "ami-830c94e3"
```

number

```
size = 6.283185
```

bool

```
termination_protection = true
```

complex/structural/collection types

list (tuple)

```
regions = ["us-east-1a", "us-east-1b"]
```

map (object)

```
tags = {env = "Production", priority = 3}
```

no type

null

```
endpoint = null
```

null represents *absence* or *omission*
*when you want to use the **underlying default** of a provider's resource configuration option*

Strings

When quoting strings you use **double quotes** eg.

```
"hello"
```

Double quoted strings can interpret **escape sequences**.

\n	Newline
\r	Carriage Return
\t	Tab
\"	Literal quote (without terminating the string)
****	Literal backslash
\uNNNN	Unicode character from the basic multilingual plane
\UNNNNNNNN	Unicode character from supplementary planes

special escape sequences:

$${	Literal ${, without beginning an interpolation sequence.
%%{	Literal %{, without beginning a template directive sequence.

Terraform also supports a "heredoc" style.
Heredoc is a UNIX style multi-line string:

```
<<EOT
hello
world
EOT
```

Strings Templates

String interpolation allows you to evaluate an expression between the markers eg. **${ .... }** and coverts it to a string.

```
"Hello, ${var.name}!"
```

String directive allows you to evaluate an conditional logic between the markers eg. **%{ .... }**

```
"Hello, %{ if var.name != "" }${var.name}%{ else }unnamed%{ endif }!
```

You can use interpolation or directives within a **HEREDOC**

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

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

You can **stripe whitespacing** that would normally be left by directive blocks by providing a trailing tilde eg. **~**

Expressions – Operators

Operators are **mathematical operations** you can preform to numbers within expressions

- Multiplication a * b
- Division a / b
- Modulus a % b
- Addition a + b
- Subtraction a – b
- Flip to Negative (* -1) -a
- Equals a == b
- Does not Equal a != b
- Less Than a < b
- Less Then or Equal a <= b
- Greater Then a > b
- Greater Then or Equal a >= b
- Or a || b
- And a && b
- Flip Boolean !a

Conditional Expressions

Terraform support ternary if else conditions.

`condition ? true_val : false_val`

```
var.a != "" ? var.a : "default-a"
```

The return type for it the if and else must be the same type:

```
var.example ? tostring(12) : "hello"
```

Expressions – For Expressions

For expressions allows you to iterative over a complex type and apply transformations

A for expression can accept as input **a list, a set, a tuple, a map, or an object**.

Uppercase each string in the provided list

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

For map you can get: **Key** and **value**

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

For a list you can get the **index**

```
[for i, v in var.list : "${i} is ${v}"]
```

Square braces **[ ]** returns a tuple

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

→ [“HELLO”, WOLRD”]

Curly braces **{ }** returns an object

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

→ { hello = “HELLO”, world = “WORLD”}

Expressions – For Expressions

An if statement can be used in a for expression to filter / reduce the amount of elements returned.

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

Implicit Element Ordering on Conversion

Since Terraform can convert a unordered type (maps objects and sets) to a ordered type (list and tuples) it will need to choose an implied ordering.

- **Maps and Objects** – stored by key A-Z
- **Sets of Strings** – stored by string A-Z
- **Everything else** – arbitrary ordering

Expressions – Splat Expressions

A **splat** expression provides a **shorter expression** for **for expressions**

What is a splat operator?
A splat operator is represented by an asterisk (*), it originates from the ruby language
Splats in Terraform are used to rollup or soak up a bunch of iterations in a *for expression*

For lists, sets and tuples

```
[for o in var.list : o.id]
[for o in var.list : o.interfaces[0].name]
```

Can be written list this

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

Expressions – Splat Expressions

Splat expressions have a special behavior when you apply them to **lists**

- If the value is anything other than a null value then the splat expression will transform it into a single-element list
- If the value is *null* then the splat expression will return an empty tuple.

This behavior is useful for modules that accept optional input variables whose default value is null to represent the absence of any value to adapt the variable value to work with other Terraform language features that are designed to work with collections.

```
variable "website" {
  type = object({
    index_document = string
    error_document = string
  })
  default = null
}

resource "aws_s3_bucket" "example" {
  # ...

  dynamic "website" {
    for_each = var.website[*]
    content {
      index_document = website.value.index_document
      error_document = website.value.error_document
    }
  }
}
```

Dynamic Blocks

Dynamic blocks allows you **dynamically construct repeatable nested blocks**

Lets say you need to create a bunch of ingress rules for an EC2 Security Group.

Define **objects** in locals:

Set **dynamic** block and utilized for_each block

```
locals {
  ingress_rules = [{
    port        = 443
    description = "Port 443"
  },
  {
    port        = 80
    description = "Port 80"
  }]
}

resource "aws_security_group" "main" {
  name   = "sg"
  vpc_id = data.aws_vpc.main.id

  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"]
    }
  }
}
```

Version Constraints

Terraform utilizes Semantic Versioning for specifying Terraform, Providers and Modules versions

Semantic Versioning is **open-standard** on how to define versioning for software management e.g. **MAJOR.MINOR.PATCH**

2.0.0 2.0.0-rc.2 2.0.0-rc.1 1.0.0 1.0.0-beta

semver.org

1.MAJOR version when you make incompatible API changes,
2.MINOR version when you add functionality in a backwards compatible manner, and
3.PATCH version when you make backwards compatible bug fixes.
Additional labels for pre-release and build metadata are available as extensions to the MAJOR.MINOR.PATCH format.

A **version constraint** is a string containing one or more conditions, separated by commas.

- = or no operator. Match exact version number e.g. “1.0.0”, “=1.0.0”
- != Excludes an exact version number e.g. “!=1.0.0”
- > >= < <= Compare against a specific version e.g. “>= 1.0.0”
- ~> Allow only the rightmost version (last number) to increment e.g. ~> 1.0.0”

Progressive Versioning

Progressive Versioning is the practice of using the latest version to keep a proactive stance of security, modernity and development agility

Practicing Good Hygiene

By being up to date you are pushing left things you will need to fix to stay compatible.
You will have to deal with smaller problems instead of dealing with a big problem later on

Run Nightly Builds of your golden images or terraform plan as a warning signal to budget the time to improve for outage.

A nightly build is an automated workflow that occurs at night when developers are asleep. If the build breaks because a change is required for the code, the developers will see this upon arrival in the morning and be able to budget accordingly.

Terraform State

What is State?

A particular condition of cloud resources at a specific time.

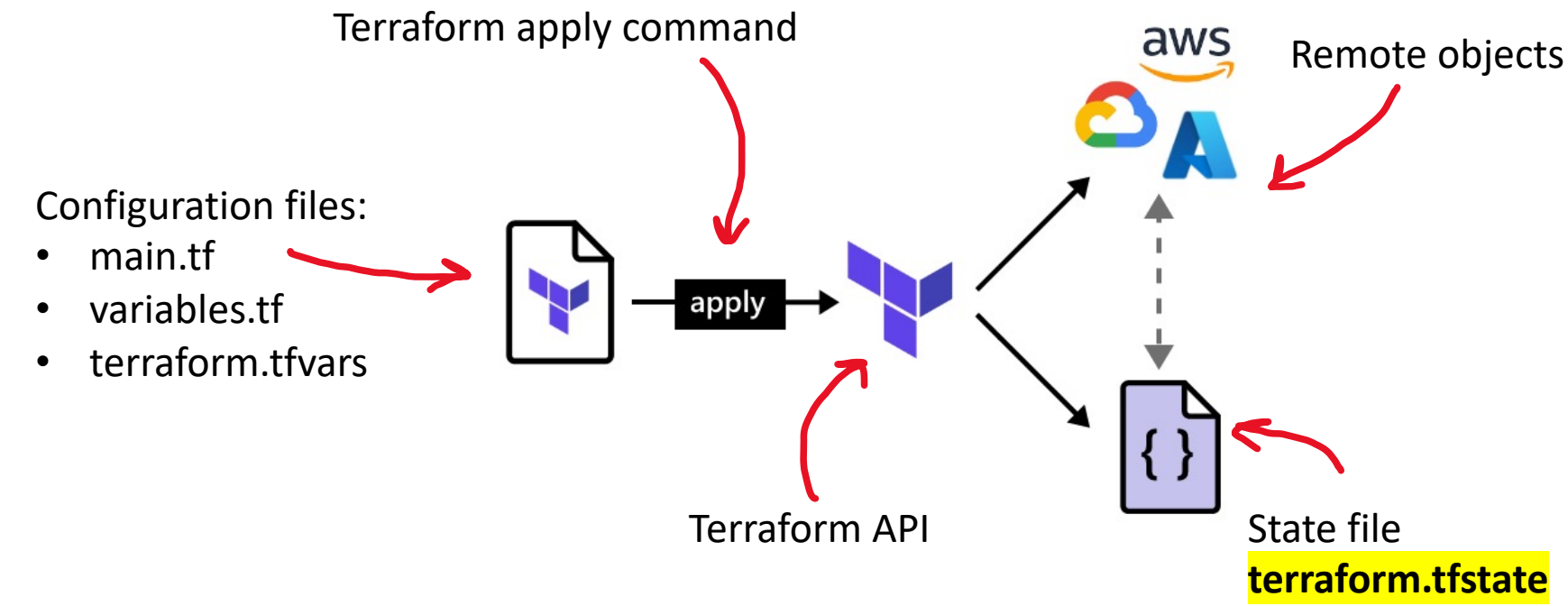
eg. We expect there to be a Virtual Machine running CentOS on AWS with a compute type of t2.micro.

How does Terraform preserve state?

When you provision infrastructure via Terraform it will create a state file named **terraform.tfstate**

This **state file is a JSON data structure** with a one-to-one mapping from **resource instances** to **remote objects**


```
{
  "version": 4,
  "terraform_version": "1.0.4",
  "serial": 1,
  "lineage": "7b78e5ae-eae4-de2e-95a2-2a947f5c
  "outputs": {},
  "resources": [
    {
      "mode": "managed",
      "type": "aws_instance",
      "name": "my_example_server",
      "provider": "provider[\"registry.terrafo
      "instances": [
        {
          "schema_version": 1,
          "attributes": {
            "ami": "ami-0c2b8ca1dad447f8a",
            "arn": "arn:aws:ec2:us-east-1:3184
            "associate_public_ip_address": tru
            "availability_zone": "us-east-1a"
```

Terraform State

terraform state **list**	List resources in the state
terraform state **mv**	Move an item in the state
terraform state **pull**	Pull current remote state and output to stdout
terraform state **push**	Update remote state from a local state
terraform state **replace-provider**	Replace provider in the state
terraform state **rm**	Remove instances from the state
terraform state **show**	Show a resource in the state

Terraform State Mv

terraform state mv allows you to:

- rename existing resources
- move a resource into a module
- move a module into a module

If you were to just rename a resource or move it to another module and run terraform apply Terraform will destroy and create the resource. State mv allows you to just change the reference so you can avoid a create and destroy action

Rename resource

```
terraform state mv packet_device.worker packet_device.helper
```

Move resource into module

```
terraform state mv packet_device.worker module.worker.packet_device.worker
```

Move module into a module

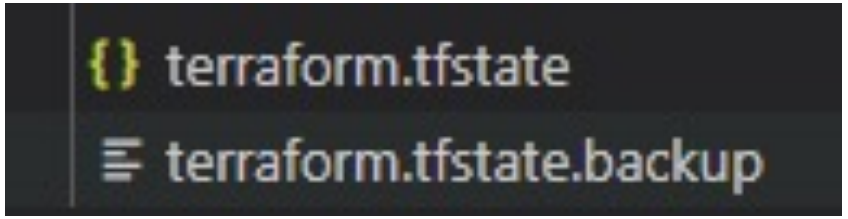
```
terraform state mv module.app module.parent.module.app
```

Terraform State Backups

All terraform state subcommands that *modify state* will write a backup file.

Read only commands will not modify state eg. list, show

Terraform will take the current state and store it in a file called **terraform.tfstate.backup**



Backups cannot be disabled. This is by design to enforce best-practice for recovery

To get rid of the backup file you need to manually delete the files

terraform Init

terraform init initializes your terraform project by:

- Downloading plugin dependencies e.g. Providers and Modules
- Create a .terraform directory
- Create a dependency lock file to enforce expected versions for plugins and terraform itself.

Terraform init is generally the first command you will run for a new terraform project
If you modify or change dependencies run **terraform init** again to have it apply the changes

terraform init **-upgade**	Upgrade all plugins to the latest version that complies with the configuration's version constraint
terraform init **-get-plugins-false**	Skip plugin installation
terraform init **-plugin-dir=PATH**	Force plugin installation to read plugins only from target directory
terraform init **–lockfile=MODE**	Set a dependency lockfile mode

Dependency lock file
.terraform.lock.hcl

State lock file
.terraform.tfstate.lock.hcl

terraform get

terraform get command is used to download and **update modules** in the root module.

When you're developer your own **Terraform Modules**
You may need to frequently pull updated modules but you do no want to initialize your state or pull new provider binaries.

Terraform Get is *lightweight* in this case because it only updates modules.

In most cases you want to use terraform init, with the exception of local module development

Writing and Modifying Terraform Code

Terraform has three CLI commands that **improve debugging configuration scripts**:

terraform **fmt**	rewrites Terraform configuration files to a standard format and style
terraform **validate**	validates the syntax and arguments of the Terraform configuration files in a directory
terraform **console**	an interactive shell for evaluating Terraform expressions

terraform fmt

This command applies a subset of the **Terraform language style conventions** along with other minor adjustments for readability

terraform fmt will by default look in the current directory and apply formatting to all .tf files.

adjusting spacing two spaces indent

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

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

syntax error

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

```
Error: Invalid block definition

  on main.tf line 11:
  11: provider "aws"
  12: {

A block definition must have block
content delimited by "{" and "}",
starting on the same line as the block header
```

terraform fmt **--diff**

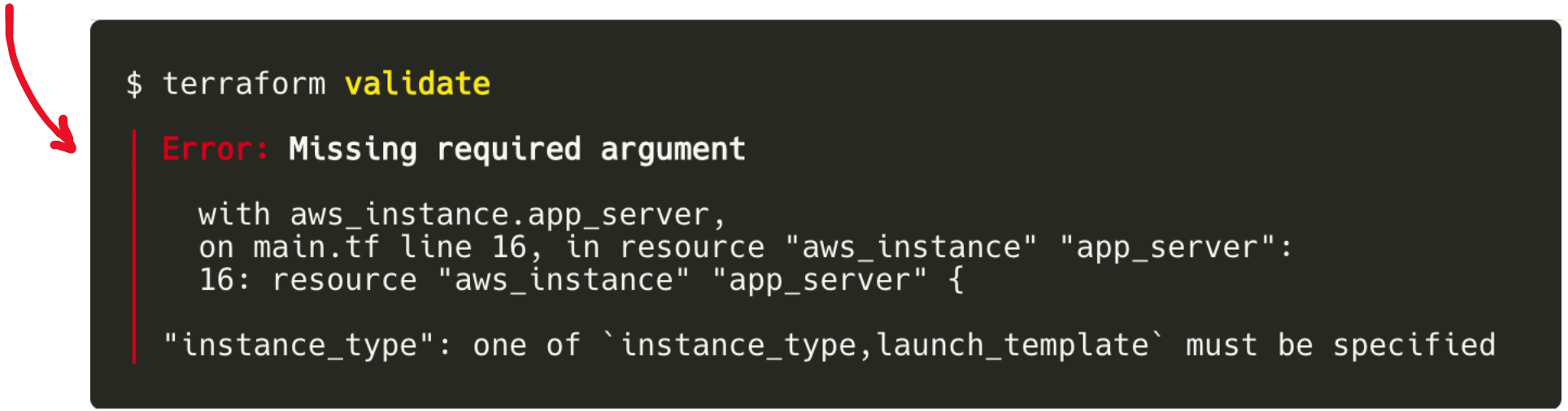
```
main.tf
--- old/main.tf
+++ new/main.tf
@@ -9,8 +9,8 @@
 }

 provider "aws" {
-    profile = "exampro"
-    region  = "us-west-2"
+  profile = "exampro"
+  region  = "us-west-2"
 }
```

terraform validate

Terraform Validate runs checks that verify whether a configuration is syntactically valid and internally consistent, regardless of any provided variables or existing state

Validate is useful for general verification of reusable modules, including correctness of attribute names and value types

We are missing an instance_type which is a required when lauching an AWS Virtual Machine



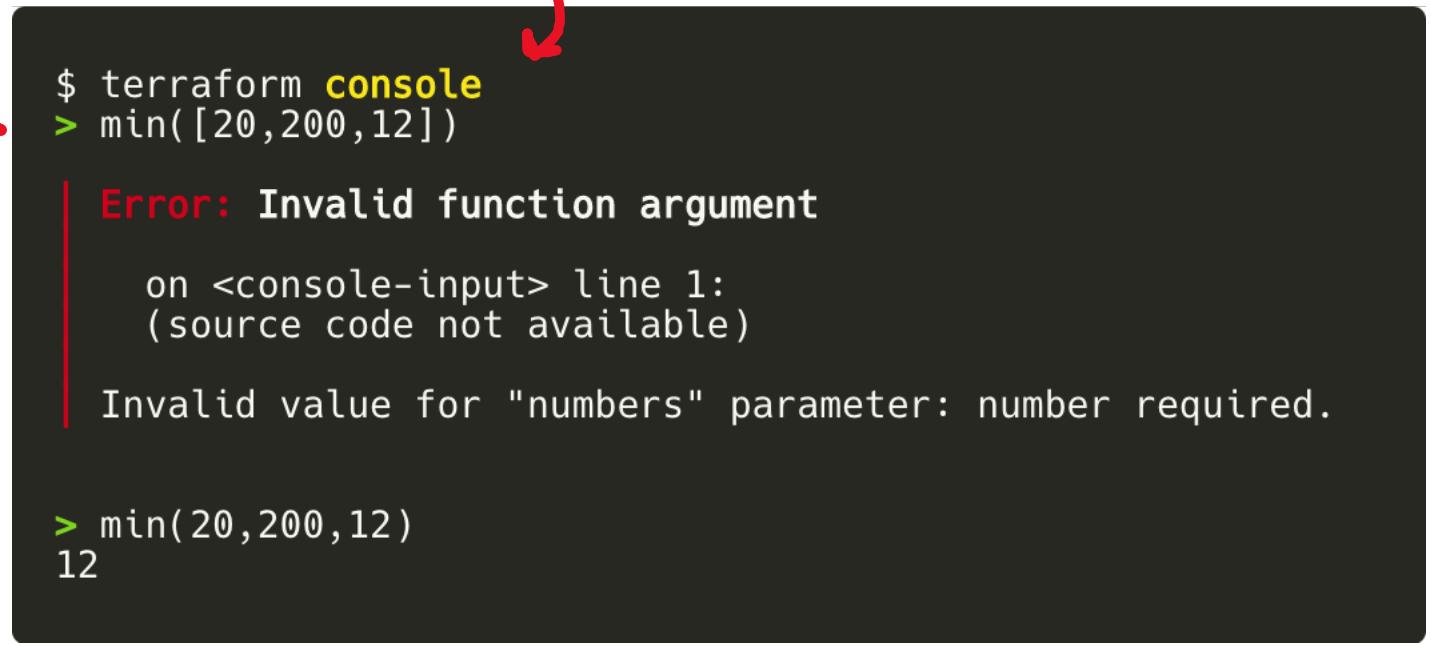
When you run terraform **plan** or terraform **apply**, validate will automatically be performed.

terraform console

Terraform console is an **interactive shell** where you can evaluate expressions.

We run a min command with the wrong arguments

We correct the argument error



Terraform Plan

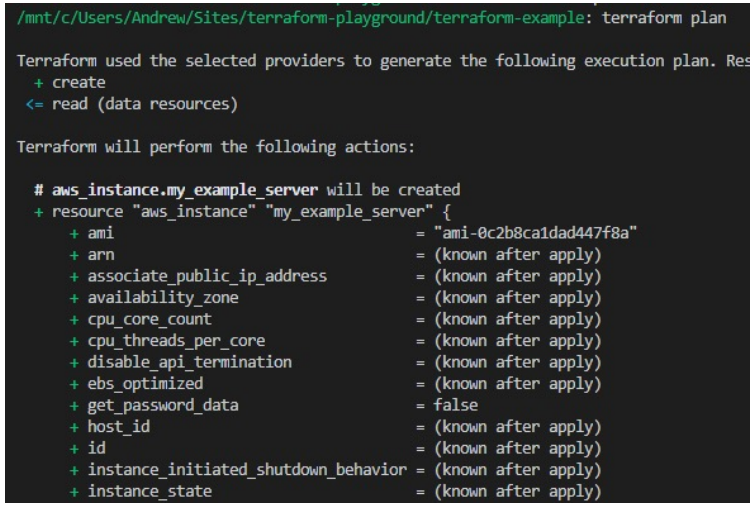
Terraform command creates an **execution plan** *(aka Terraform Plan).*

A plan consist of:

- Reading the current state of any already-existing remote objects to make sure that the Terraform state is up-to-date.
- Comparing the current configuration to the prior state and noting any differences.
- Proposing a set of change actions that should, if applied, make the remote objects match the configuration.

Terraform plan **does not carry out** proposed changed.

A Terraform Plan file is binary file. If you open it up you'll just see machine code



Speculative Plans

When you run **terraform apply**

Terraform will output the description of the effect of the plan but without any intent to actually apply it.

Saved Plans

When you run **terraform apply -out=FILE**

You can generate a saved plan file which you can then pass along to terraform apply. eg **terraform apply FILE**

When using save planed it will not prompt you to confirm and will act like auto-approve

Terraform Apply

Terraform apply command executes the actions proposed in an execution plan

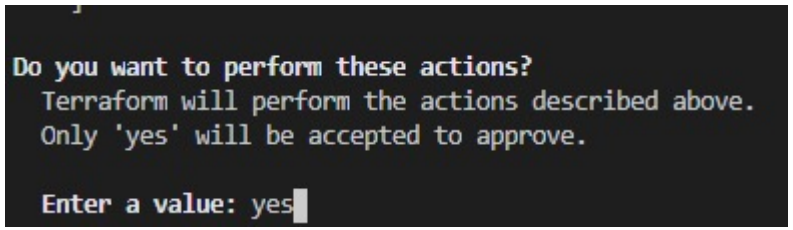
Automatic Plan Mode

When you run **terraform apply**

Executes plan, validate and the apply.

Requires users to **manually approve** the plan by writing “yes”

Terraform apply **–auto-approve** flag will automatically approve the plan.



Saved Plan Mode

When you provide a filename to terraform to saved plan file **terraform apply FILE**

performs exactly the steps specified by that plan file. It does not prompt for approval; if you want to inspect a plan file before applying it, you can use terraform show.

Manage Resource Drift

Drift (Configuration or Infrastructure) is when your expected resources are in different state then your expected state

We can resolve Drift in three ways in Terraform:

Replacing Resources
When a resource has become damaged or degraded that cannot be detected by Terraform we can use the **–replace** flag

Importing Resources
When an approved manual addition of resource needs to be added to our state file
We use the **import** command.

Refresh State
When an approved manual configuration of a resource has changed or removed
We use the **–refresh-only** flag to reflect the changes in our state file

Replacing Resources

Terraform Taint is used to **mark a resource** for *replacement*, the next time you run apply.

Why would want to mark a resource for replacement?

```
terraform taint aws_instance.my_web_app
```

A cloud resource can become **degraded or damaged** and you want to return the expected resource to a healthy state

*Terraform taint was **deprecated** in 0.152*

It is recommended in 0.152+ to use the **-replace** flag and providing a resource address

```
terraform apply -replace="aws_instance.example[0]"
```

The replace flag is available on **plan** and **apply**

The replace flag appears to only work for a single resource

Resource Addressing

A resource address is a string that **identifies zero or more resource instances** in your configuration.

An address is composed of two parts:

[module path][resource spec]

module.module_name[module index]

A module path addresses a module within the tree of modules

module A namespace for modules
module_name User-defined name of the module
[module index] When multiple specific a index

resource_type.resource_name[instance index]

A resource spec addresses a specific resource instance in the selected module

resource_type Type of the resource being addressed
resource_name User-defined name of the resource
[instance index] when multiple specific a index

```
resource "aws_instance" "web" {
  # ...
  count = 4
}
```

aws_instance.**web**[3]

Select the 3rd Virtual Machine

terraform import

The terraform import command is used to import ***existing resources*** into Terraform

Define a placeholder for your imported resource in configuration file.

You can leave the body blank and fill it in after importing. It will not be autofilled.

```
resource "aws_instance" "example" {
  # ...instance configuration...
}
```

terraform import <**RESOURCE_ADDRESS**> <**ID**>

Proceed to importing your import file.

```
terraform import aws_instance.example i-abcd1234
```

The command can only import one resource at a time.

Not all resources are importable, you need to check the bottom of resource documentation for support

Terraform refresh

The **terraform refresh** command **reads the current settings** from all managed remote objects **and updates the Terraform state to match.**

The terraform refresh command is an alias for the refresh only and auto approve

```
terraform refresh
```

```
terraform apply -refresh-only -auto-approve
```

Terraform refresh will not modify your real remote objects, but it will modify the Terraform state.

Terraform refresh has been ***deprecated*** and with the refresh-only flag because it was not safe since it did not give you an opportunity to review proposed changes before updating state file

Refresh-Only Mode

The **–refresh-only** flag for terraform plan or apply allows you to refresh and update your state file without making changes to your remote infrastructure.

Scenario

Imagine you create a terraform script that deploys a Virtual Machine on AWS
You ask an engineer to terminate the server, and instead of updating the terraform script they mistakenly terminate the server via the AWS Console.

You run….

terraform apply

- Terraform will notice that the VM is missing
- Terraform will propose to create a new VM

The State File is correct
Changes the infrastructure to match state file

terraform apply **–refresh-only**

- Terraform will notice that the VM you provisioned is missing.
- With the refresh-only flag that the missing VM is intentional
- Terraform will propose to delete the VM from the state file

The State File is wrong
Changes the state file to match infrastructure

Terraform Troubleshooting

There are **four types of errors** you can encounter with Terraform:

Language errors
Terraform encounters a syntax error in your configuration for the Terraform or HCL Language

terraform fmt
terraform validate
terraform version

State errors
Your resources state has changed from the expected state in your configuration file

terraform refresh
terraform apply
terraform –replace flag

Core errors
A bug has occurred with the core library

TF_LOG
Open Github Issue

Provider errors
The provider's API has changed or does not work as expected due to emerging edge cases

TF_LOG
Open Github Issue

Easy to Solve

Harder to Solve

Debugging Terraform

Terraform has detailed logs which can be enabled by setting the **TF_LOG environment** variable to:

- TRACE
- DEBUG
- INFO
- WARN
- ERROR
- JSON — outputs logs at the TRACE level or higher, and uses a parseable JSON encoding as the formatting.

Logging can be enabled separately:

- TF_LOG_CORE
- TF_LOG_PROVIDER

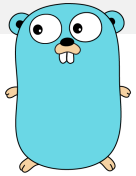
takes the same options as TF_LOG

Choose where you want to log with **TF_LOG_PATH**

Terraform Log example

```
2021-04-02T15:36:08.477-0400 [DEBUG] provider.terraform-provider-aws_v3.34.0_x5: plugin address:
address=/var/folders/rf/mz_yf4bx0hv1r8m7yqw840jc0000gn/T/plugin730416856 network=unix timestamp=2021-04-02T15:36:08.476-0400
2021-04-02T15:36:08.477-0400 [DEBUG] provider: using plugin: version=5
2021-04-02T15:36:08.525-0400 [TRACE] provider.stdio: waiting for stdio data
2021-04-02T15:36:08.525-0400 [TRACE] GRPCProvider: GetProviderSchema
2021-04-02T15:36:08.593-0400 [TRACE] GRPCProvider: Close
2021-04-02T15:36:08.596-0400 [DEBUG] provider.stdio: received EOF, stopping recv loop: err="rpc error: code = Unavailable desc = transport...
2021-04-02T15:36:08.598-0400 [DEBUG] provider: plugin process exited: path=.terraform/providers/registry.terraform.io/hashicorp/aws/3.34...
2021-04-02T15:36:08.598-0400 [DEBUG] provider: plugin exited
2021-04-02T15:36:08.598-0400 [TRACE] terraform.NewContext: complete
2021-04-02T15:36:08.599-0400 [TRACE] backend/local: finished building terraform.Context
2021-04-02T15:36:08.599-0400 [TRACE] backend/local: requesting interactive input, if necessary
2021-04-02T15:36:08.599-0400 [TRACE] Context.Input: Prompting for provider arguments
2021-04-02T15:36:08.599-0400 [TRACE] Context.Input: Provider provider.aws declared at main.tf:15,1-15
2021-04-02T15:36:08.600-0400 [TRACE] Context.Input: Input for provider.aws: map[string]cty.Value{}
2021-04-02T15:36:08.600-0400 [TRACE] backend/local: running validation operation
2021-04-02T15:36:08.600-0400 [INFO]  terraform: building graph: GraphTypeValidate
2021-04-02T15:36:08.600-0400 [TRACE] Executing graph transform *terraform.ConfigTransformer
```

Debugging Terraform – Crash Log



If Terraform ever crashes (a "panic" in the **Go runtime**), it saves a log file with the debug logs from the session as well as the panic message and backtrace to crash.log

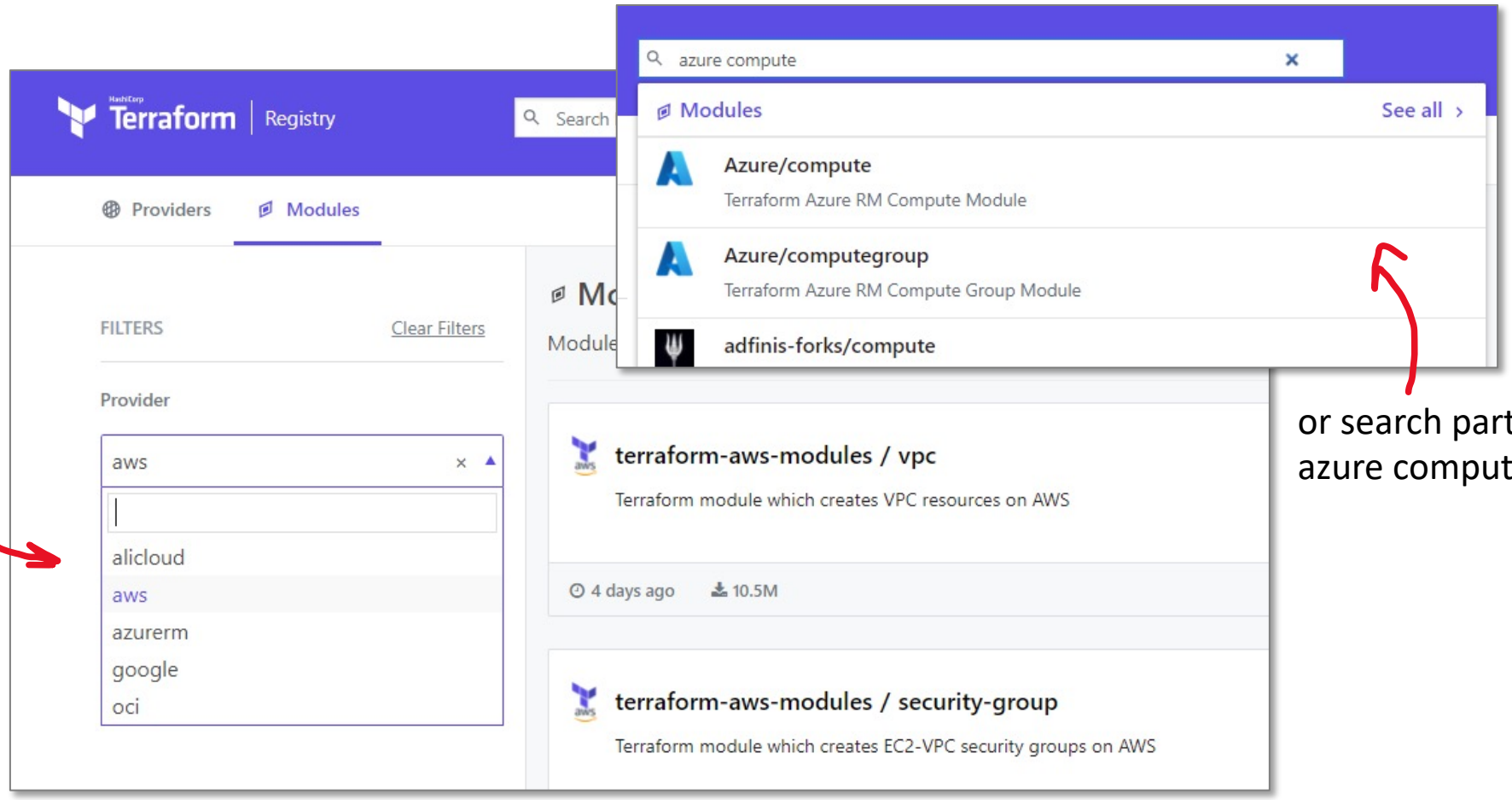
```
panic: runtime error: invalid memory address or nil pointer dereference

goroutine 123 [running]:
panic(0xabc100, 0xd93000a0a0)
    /opt/go/src/runtime/panic.go:464 +0x3e6
github.com/hashicorp/terraform/builtin/providers/aws.resourceAwsSomeResourceCreate(...)
    /opt/gopath/src/github.com/hashicorp/terraform/builtin/providers/aws/resource_aws_some_resource.go:123 +0x123
github.com/hashicorp/terraform/helper/schema.(*Resource).Refresh(...)
    /opt/gopath/src/github.com/hashicorp/terraform/helper/schema/resource.go:209 +0x123
github.com/hashicorp/terraform/helper/schema.(*Provider).Refresh(...)
    /opt/gopath/src/github.com/hashicorp/terraform/helper/schema/provider.go:187 +0x123
github.com/hashicorp/terraform/rpc.(*ResourceProviderServer).Refresh(...)
    /opt/gopath/src/github.com/hashicorp/terraform/rpc/resource_provider.go:345 +0x6a
reflect.Value.call(...)
    /opt/go/src/reflect/value.go:435 +0x120d
reflect.Value.Call(...)
    /opt/go/src/reflect/value.go:303 +0xb1
net/rpc.(*service).call(...)
    /opt/go/src/net/rpc/server.go:383 +0x1c2
created by net/rpc.(*Server).ServeCodec
    /opt/go/src/net/rpc/server.go:477 +0x49d
```

This log file is meant to be passed along to the developers via a GitHub Issue.
As a user, you're not required to dig into this file

Finding Modules

Terraform Modules can be publicly found in the Terraform Registry

You can filter based on popular providers



or search partial terms eg. azure compute

*Only **verified modules** will be displayed in search terms*

Using Modules

Public Modules

Terraform Registry is integrated **directly into** Terraform

The syntax for specifying a registry module is
<NAMESPACE>/<NAME>/<PROVIDER>

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

terraform init command will **download and cache any modules** referenced by a configuration

Private Modules

Private registry modules have source strings of the form
<HOSTNAME>/<NAMESPACE>/<NAME>/<PROVIDER>

```
module "vpc" {
  source =
"app.terraform.io/example_corp/vpc/aws"
  version = "0.9.3"
}
```

To configure private module access, you need to authenticate against Terraform Cloud via **terraform login**

Alternatively you can create a user API Token and manually configure credentials in the CLI config file.

Publishing Modules

Anyone can publish and share modules on the Terraform Registry.

Published modules support:

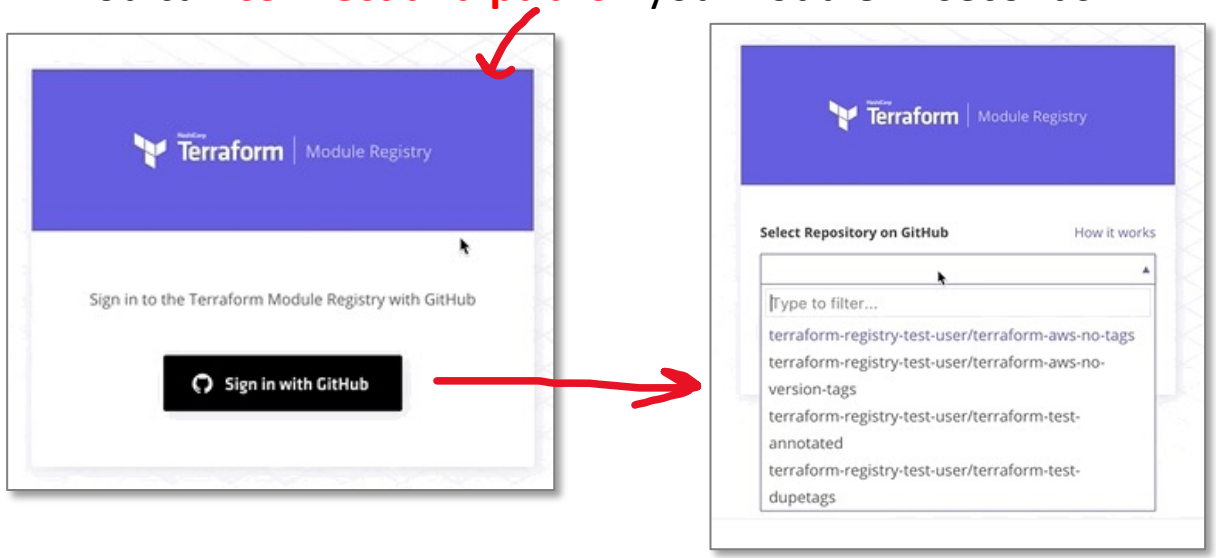
- Versioning
- automatically generate documentation
- allow browsing version histories
- show examples
- READMEs

Repos names must be in the following format:
terraform-<PROVIDER>-<NAME>

Public modules are managed via a **public** Git repo on **GitHub**

Once a module is registered, to push updates you simply push new versions to properly formed Git Tags

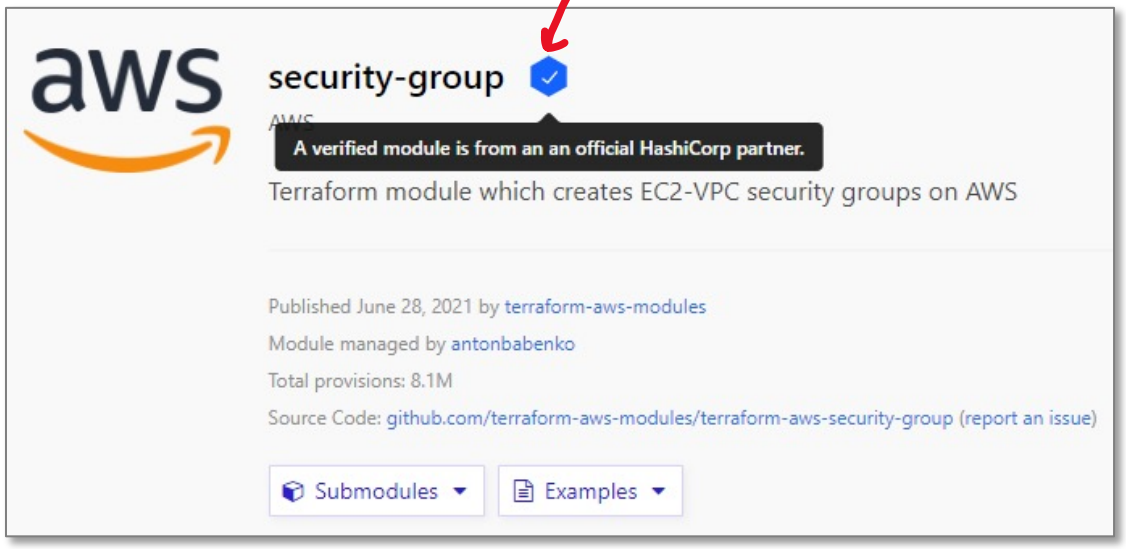
You can **connect and publish** you module in seconds



Verified Modules

Verified modules are reviewed by HashiCorp and actively maintained by contributors to stay up-to-date and compatible with both Terraform and their respective providers.

The verified badge appears next to the module



Verified modules are expected to be actively maintained by HashiCorp partners
verified badge **isn’t indicative of flexibility or feature support**

- very simple modules can be verified just because they're great examples of modules
- unverified module could be extremely high quality and actively maintained
- unverified module shouldn't be assumed to be poor quality
- Unverified means it hasn't been created by a HashiCorp partner

Standard Module Structure

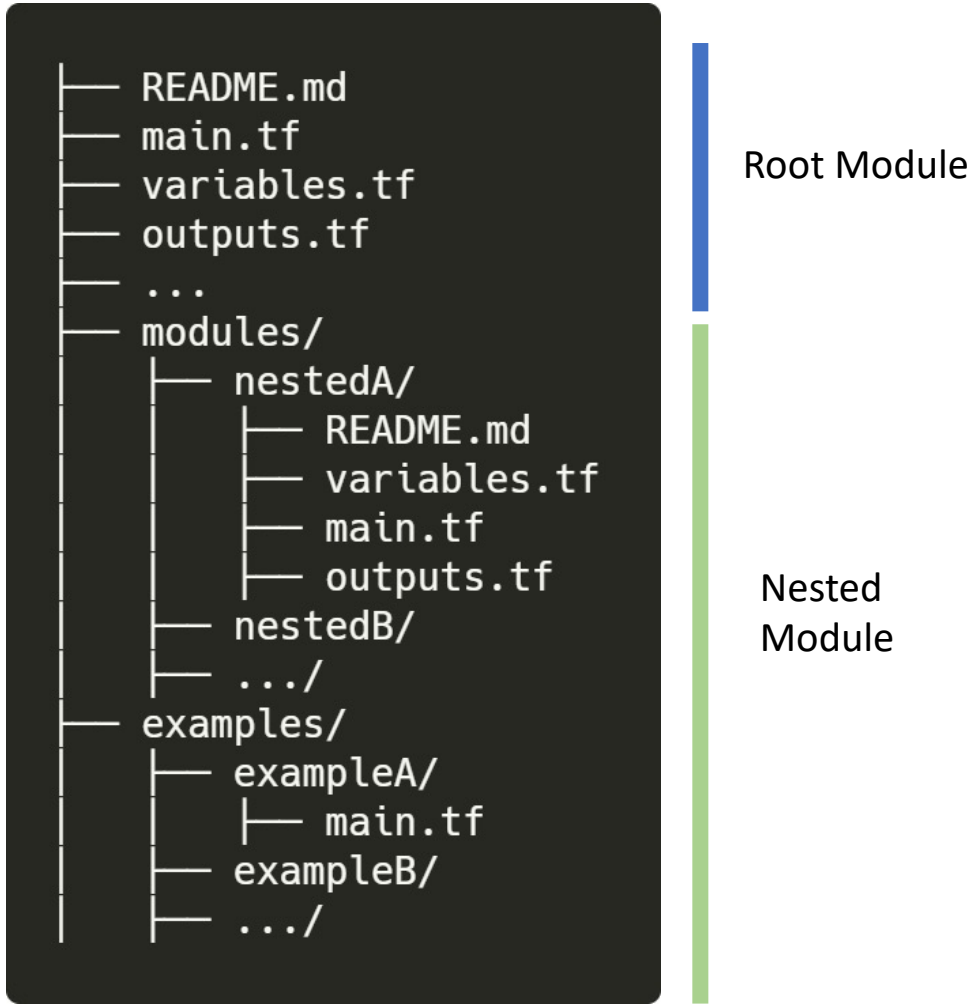
The Standard Module Structure is a file and directory layout recommend for module development

The primary entry point is the **Root Module.**
These are required files in the root directory:

- Main.tf - the entry point file of your module
- Variables.tf – variable that can be passed in
- Outputs.tf – Outputed values
- README – Describes how the module works
- LICENSE – The license under which this module is available

Nested modules are optional must be contained in the **modules/** directory:

- A submodule that contains a README is consider usable by external users
- A submodule that does not contain a README is consider internal use only
- Avoid using relative paths when sourcing module blocks.



Terraform Workflows

The core Terraform workflow has three steps:

1. **Write** - Author infrastructure as code.
2. **Plan** - Preview changes before applying.
3. **Apply** - Provision reproducible infrastructure.

As you team and requirements grow your workflow will evolve.
Lets look at what this workflow will look like for:

- Individual Practitioner (One person team)
- Teams using OSS
- Teams using Terraform Cloud

Team Workflows – Individual Practitioner

Write

- You write your Terraform configuration in your editor of choice
- You'll store your terraform code in a VCS e.g. Github
- You repeatedly run terraform plan and validate to find syntax errors.
- Tight feedback loop between editing code and running test commands

Plan

- When the developer is confident with their work in the write step they commit their code to their local repository.
- They may be only using a single branch e.g. main
- Once their commit is written they'll proceed to apply

Apply

- They will run terraform apply and be prompted to review their plan
- After their final review they will approve the changes and await provisioning
- After a successful provision they will push their local commits to their remote repository.

Team Workflows– Team

Write

- Each team members writes code locally on their machine in their editor of choice
- A team member will store their code to a branch in their code repository
  - Branches help avoid conflicts while a member is working on their code
  - Branches will allow an opportunity to resolve conflict during a merge into main
- Terraform plan can be used as a quick feedback loop for small teams
- For larger teams a concern over sensitive credentials becomes a concern.
  - A CI/CD process may be implemented so the burden of credentials is abstracted away

Plan

- When a branch is ready to be incorporated on Pull Request an Execution Plan can be generated and displayed within the Pull Request for Review

Apply

- To apply the changes the merge needs to be approved and merged, which will kick of a code build server that will run terraform apply.

- The DevOps team has to setup and maintain their own CI/CD Pipeline
- They have to figure out how to store the state file e.g. Standard Backend remote state
- They are limited in their access controls (they can't be granular about what actions are allowed to performed by certain members e.g. apply, destroy
- They have to figure out a way to safely store and inject secrets into their build server's runtime environment
- Managing multiple environments can make the overhead of the infrastructure increase dramatically.

Team Workflows– Terraform Cloud

Write

- A team will use Terraform Cloud as their remote backend.
- Inputs Variables will be stored on Terraform Cloud instead of the local machines.
- Terraform Cloud integrates with your VCS to quickly setup a CI/CD pipeline
- A team member writes code to branch and commits per usual

Plan

- A pull request is create by a team member and Terraform Cloud will generate the speculative plan for review in the VCS. The member can also review and comment on the plan in Terraform Cloud.

Apply

- After the Pull request is merge Terraform Cloud runtime environment will perform a Terraform apply. A team member can Confirm and apply the changes.

Terraform Cloud streamlines a lot of the CI/CD effort, storing and securing sensitive credentials and makes it is easier to go back and audit the history of multiple runs.

Backends

Each Terraform configuration can specify a backend, which defines where and how operations are performed, where state snapshots are stored

Terraform's backends are divided into two types:

Standard backends

- only store state
- does not perform terraform operations eg. Terraform apply
  - To perform operations you use the CLI on your local machine
- **third-party backends** are Standard backends e.g. AWS S3

Enhanced backends

- can both store state
- can perform terraform operations

enhanced backends are subdivided further:

- **local** – files and data are stored on the local machine executing terraform commands
- **remote** – files and data are stored in the cloud eg. Terraform Cloud

Standard Backends

Simple Storage Service (S3) *locking via DynamoDB*
AWS Cloud Storage

AzureRM *with locking*
Blob Storage Account

Google Cloud Storage (GCS) *with locking*
Google Cloud's Object Storage

Alibaba Cloud Object Storage Service (OSS)
Cloud Storage *locking via TableStore*

OpenStack Swift *with locking*
Rackspace's OpenStack Private Cloud Storage

Tencent Cloud Object Storage (COS) *with locking*

Manta (Triton Object Storage) *with locking*
Joynet's Cloud Storage

Artifactory *no locking* ❌
a universal repository manager

HashiCorp Consul *with locking*
service networking platform (service mesh)

etcd *no locking* and **etcdv3** *with locking*
A distributed, reliable key-value store for the most critical data of a distributed system

Postgres database *with locking*
Relational database

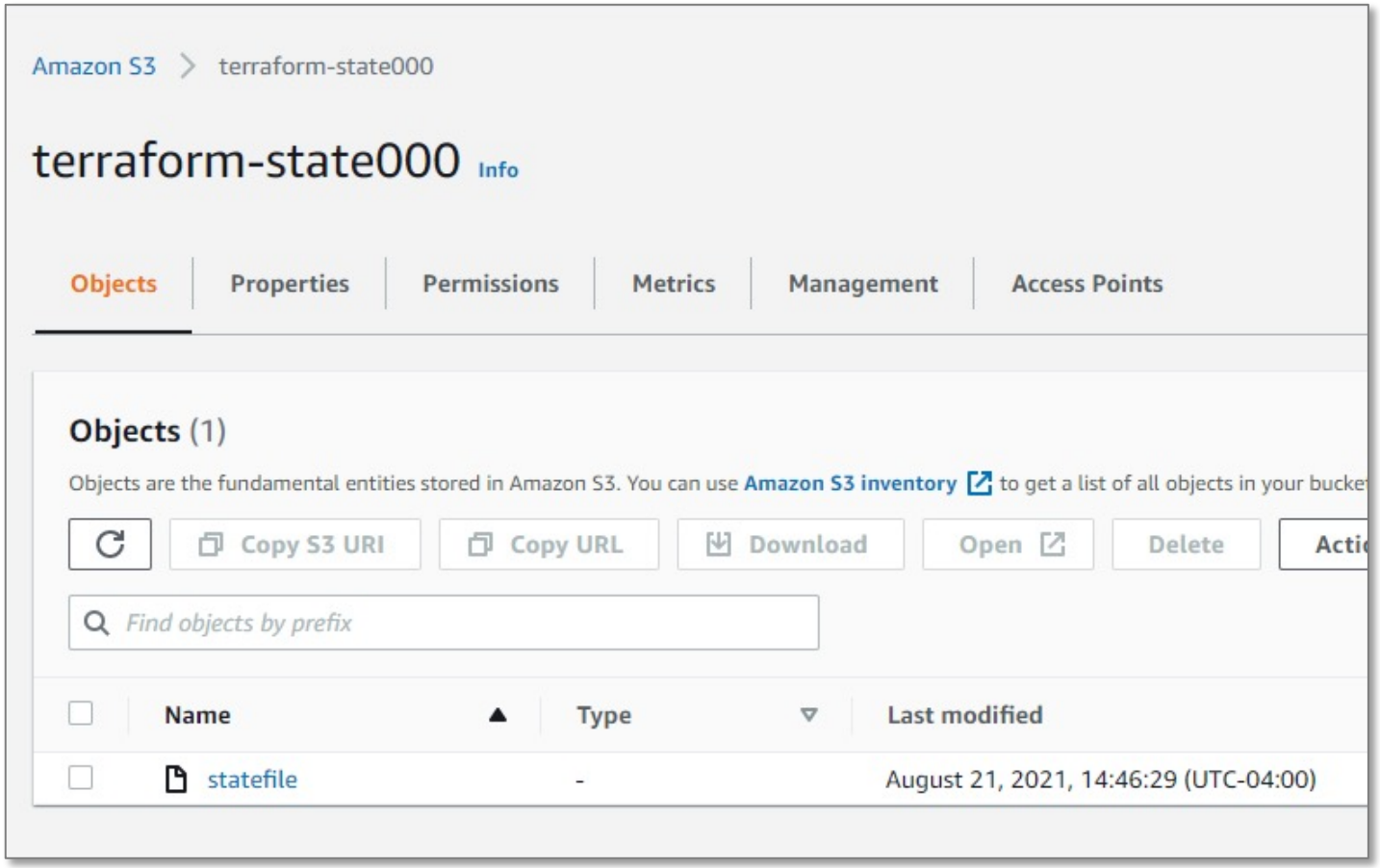
Kubernetes secret *with locking*
Secrets storage in K8 cluster

HTTP Protocol ***optional*** *locking*
Use a REST API to setup a custom remote backend

Standard Backends

```
backend "s3" {
  bucket = "terraform-state000"
  key    = "statefile"
  region = "us-east-1"
}
```

The backup of a state file will reside on your local machine.



Configuring a standard backend *does not require* a Terraform Cloud account or workspace

Local Backends

The local backend:

- stores state on the local filesystem
- locks that state using system APIs
- performs operations locally

By default, you are using the backend state when you have no specified backend

```
terraform {
}
```

You specific the backend with argument **local**, and you can change the path to the local file and **working_directory**

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

You can set a backend to reference another state file so you can read its outputted values.

This is way of **cross-referencing stacks**

```
data "terraform_remote_state" "networking" {
  backend = "local"

  config = {
    path = "${path.module}/networking/terraform.tfstate"
  }
}
```

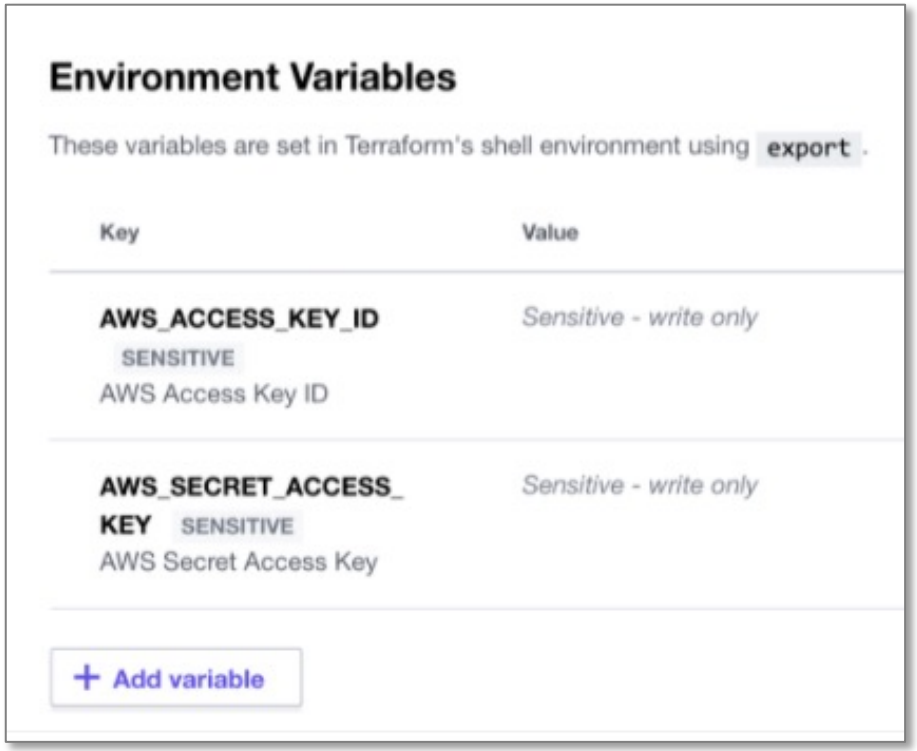
Remote Backend

A Remote backend uses the Terraform platform which is either:

- Terraform Cloud
- Terraform Enterprise

With a remote backend when terraform apply is performed via the CLI
The Terraform Cloud Run Environment is responsible for executing the operation

Because the Terraform Cloud Run Environment is executing the command. Your provider credentials **need to be configured** in Environment Variables in Terraform Cloud



Remote Backend

When using a remote backend you need to set a Terraform Cloud **Workspaces**

You can set a single workspace via **name**

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

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

You can set multiple workspaces via **prefix**

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

    workspaces {
      prefix = "my-app-"
    }
  }
}
```

Setting both name and prefix will result in an error.

On terraform apply you will have to choose which workspace you want to apply the operation

```
Initializing the backend...

Successfully configured the backend "remote"! Terraform will automatically
use this backend unless the backend configuration changes.

The currently selected workspace (default) does not exist.
  This is expected behavior when the selected workspace did not have an
  existing non-empty state. Please enter a number to select a workspace:

  1. dev
  2. prod

  Enter a value:
```

Backend Initialization

The **-backend-config** flag for **terraform init** can be used for partial backend configuration

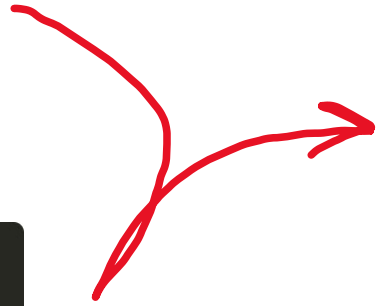
In situations where the backend settings are dynamic or sensitive
and so cannot be statically specified in the configuration file.

main.tf

```
terraform {
  required_version = "~> 0.12.0"

  backend "remote" {}
}
```

backend.hcl

```
workspaces { name = "workspace" }
hostname     = "app.terraform.io"
organization = "company"
```



```
terraform init -backend-config=backend.hcl
```

terraform_remote_state

terraform_remote_state data source **retrieves the root module output values from another Terraform configuration**, using the latest state snapshot from the remote backend.

Remote Backend

```
data "terraform_remote_state" "vpc" {
  backend = "remote"

  config = {
    organization = "hashicorp"
    workspaces = {
      name = "vpc-prod"
    }
  }
}
resource "aws_instance" "foo" {
  subnet_id = data.terraform_remote_state.vpc.outputs.subnet_id
}
```

Local Backend

```
data "terraform_remote_state" "vpc" {
  backend = "local"

  config = {
    path = "..."
  }
}

resource "aws_instance" "my_server" {
  # ...
  subnet_id = data.terraform_remote_state.vpc.outputs.subnet_id
}
```

- Only the root-level output values from the remote state snapshot are exposed
- Resource data and output values from nested modules are not accessible
- To make a nested module output value accessible as a root module output value, you must **explicitly configure a passthrough in the root module**

```
module "app" {
  source = "..."
}

output "app_value" {
  value = module.app.example
}
```

Alternative to terraform_remote_state

terraform_remote_state only exposes output values, its user must have access to the entire state snapshot, which often includes some sensitive information.

It recommend explicitly publishing data for external consumption
to a separate location instead of accessing it via remote state

Use **a data source** and reference resources whenever you can:

```
data "aws_s3_bucket" "selected" {
  bucket = "bucket.test.com"
}

data "aws_route53_zone" "test_zone" {
  name = "test.com."
}

resource "aws_route53_record" "example" {
  zone_id   = "${data.aws_route53_zone.test_zone.id}"
  name      = "bucket"
  type      = "A"

  alias {
    name    = "${data.aws_s3_bucket.selected.website_domain}"
    zone_id = "${data.aws_s3_bucket.selected.hosted_zone_id}"
  }
}
```

State Locking

Terraform will lock your state for all operations that could write state.
This prevents others from acquiring the lock and potentially corrupting your state

State locking happens automatically on all operations that could write state
You won't see any message that it is happening. If state locking fails

Disabling Locking
You can disable state locking for most commands with the **-lock** flag but it is not recommended

Terraform does not output when a lock is complete, However, If acquiring the lock is taking longer than expected, Terraform will output a status message

Force Unlock
Terraform has a **force-unlock** command to manually unlock the state if unlocking failed.
If you unlock the state when someone else is holding the lock **it could cause multiple writers**.
Force unlock should only be used to unlock your own lock in the situation where automatic unlocking failed.
To protect you, the force-unlock command **requires a unique lock ID**

- Terraform will output this lock ID if unlocking fails

```
terraform force-unlock 1941a539b-ff25-76ef-92d-547ab37b24d -force
```

-force flag will skip use confirmation

Protecting Sensitive Data

Terraform State file **can contain sensitive data** eg. long-lived AWS Credentials
and is a possible **attack vector** for malicious actors.

Local State

When using local backend, state is stored in plain-text JSON files.

- You need to be careful you don't share this state file with anyone
- You need to be careful you don't commit this file to your git repository

Remote State with Terraform Cloud

When using the Terraform Cloud remote backend:

- That state file is held in memory and is not persisted to disk
- The state file is encrypted-at-rest
- The state file is encrypted-in-transit
- With Terraform Enterprise you have detailed audit logging for tamper evidence

Remote State with Third-Party Storage

You can store state with various third-party backends.

You need to carefully review your backends capabilities to determine if will meet your security and compliance requirements.

Some backends are not by default as secure as they could be:

- eg. With AWS S3 you have to ensure encryption and versioning is turned on, you need to create a custom trail for data events

Terraform Ignore File

When executing a **remote** plan or apply in a CLI-driven run,
an archive of your configuration directory is uploaded to Terraform Cloud.

You can define paths to ignore from upload via a **.terraformignore** file at
the root of your configuration directory.

If this file is not present, the archive will exclude the following **by default**:

- .git/ directories
- .terraform/ directories (exclusive of .terraform/modules)

.terraformignore works just like a .gitignore with the only difference is that you cannot have multiple .terraformignore files in subdirectories. Only the file in the root directory will be read

Resources

Resources in configuration files represent **infrastructure objects** e.g. Virtual Machines, Databases, Virtual Network Components, Storage…..

A resource type determines the kind of infrastructure object:
e.g. **aws_instance** is a AWS EC2 instance

```
resource "aws_instance" "web" {
  ami           = "ami-a1b2c3d4"
  instance_type = "t2.micro"
}
```

A resource belongs to a provider.

Some resource types provide a **special timeouts nested block** argument that allows you to customize how long certain operations are allowed to take before being considered to have failed

```
resource "aws_db_instance"
"example" {
  # ...

  timeouts {
    create = "60m"
    delete = "2h"
  }
}
```

Complex Types

A *complex* type is a type that groups multiple values into a single value. Complex types are represented by type constructors, but several of them also have shorthand keyword versions.

There are two categories of complex types:

- collection types (for grouping similar values)
  - List, Map, Set
- structural types (for grouping potentially dissimilar values)
  - Tuple , Object

Collection Types

A *collection* type allows multiple values of *one* other type to be grouped together as a single value.
The type of value *within* a collection is called its *element type.*

The three kinds of collection type **list, map, set**

List – Its like an array, you use an integer as the index to retrieve the value

```
variable "planet" {
  type    = list
  default = ["mars", "earth", "moon"]
}
username = var.users[0]
```

Map its like a ruby hash or single nested json object. You use a key as the index to retrieve the value

```
variable "plans" {
  type = map
  default = {
    "PlanA"  = "10 USD"
    "PlanB" = "50 USD"
    "PlanC" = "100 USD"
  }
}
plan = var.plans["PlanB"]
```

Set - Is similar to a list but has no secondary index or preserved ordering, all values must of the same type and will be cast to match based on first element

```
> toset(["a", "b", 3])
[
  "a",
  "b",
  "3",
]
```

Structural Types

A *structural* type allows multiple values of *several distinct types* to be grouped together as a single value.
Structural types require a ***schema*** as an argument, to specify which types are allowed for which elements.

```
variable "with_optional_attribute" {
  type = object({
    a = string           # a required attribute
    b = optional(string) # an optional attribute
  })
```

The two kinds of structural type, **object** and **tuple**

Object is a map with more explicit keying

object({ name=string, age=number })

```
{
  name = "John"
  age  = 52
}
```

Tuple. Multiple return types with parameters

tuple([string, number, bool])

```
["a", 15, true]
```

Built-in Functions

Terraform language includes a number of built-in functions that you can call from within expressions to transform and combine values

- Numeric Functions
- String Functions
- Collection Functions
- Encoding Functions
- Filesystem Functions
- Date and Time Functions
- Hash and Crypto Functions
- IP Network Functions
- Type Conversion Functions

Numeric Functions

abs returns the absolute value of the given number

```
> abs(23)
23
> abs(0)
0
> abs(-12.4)
12.4
```

ceil returns the closest whole number that is greater than or equal to the given value

```
> ceil(5)
5
> ceil(5.1)
6
```

floor returns the closest whole number that is less than or equal to the given value, which may be a fraction

```
> floor(5)
5
> floor(4.9)
4
```

min takes one or more numbers and returns the smallest number from the set

max takes one or more numbers and returns the greatest number from the set

Log returns the logarithm of a given number in a given base

```
> log(50, 10)
1.6989700043360185
> log(16, 2)
4
```

Numeric Functions

parseint parses the given string as a representation of an integer in the specified base and returns the resulting number

```
> parseint("100", 10)
100

> parseint("FF", 16)
255

> parseint("-10", 16)
-16

> parseint("1011111011101111", 2)
48879

> parseint("aA", 62)
656

> parseint("12", 2)

Error: Invalid function argument

Invalid value for "number" parameter:
cannot parse "12" as a base 2 integer.
```

pow calculates an exponent, by raising its first argument to the power of the second argument.

```
> pow(3, 2)
9
> pow(4, 0)
1
```

signum determines the sign of a number, returning a number between -1 and 1 to represent the sign

```
> signum(-13)
-1
> signum(0)
0
> signum(344)
1
```

String Functions

chomp removes newline characters at the end of a string.

```
> chomp("hello\n")
hello
> chomp("hello\r\n")
hello
> chomp("hello\n\n")
hello
```

format produces a string by formatting a number of other values according to a specification string

```
> format("Hello, %s!", "Ander")
Hello, Ander!
> format("There are %d lights", 4)
There are 4 lights
```

formatlist produces a list of strings by formatting a number of other values according to a specification string

```
> formatlist("Hello, %s!", ["Valentina", "Ander", "Olivia", "Sam"])
[
  "Hello, Valentina!",
  "Hello, Ander!",
  "Hello, Olivia!",
  "Hello, Sam!",
]
> formatlist("%s, %s!", "Salutations", ["Valentina", "Ander", "Olivia", "Sam"])
[
  "Salutations, Valentina!",
  "Salutations, Ander!",
  "Salutations, Olivia!",
  "Salutations, Sam!",
]
```

String Functions

indent adds a given number of spaces to the beginnings of all but the first line in a given multi-line string

```
> "  items: ${indent(2, "[\n  foo,\n  bar,\n]\n")}"
  items: [
    foo,
    bar,
  ]
```

join produces a string by concatenating together all elements of a given list of strings with the given delimiter

```
> join(", ", ["foo", "bar", "baz"])
foo, bar, baz
> join(", ", ["foo"])
foo
```

lower converts all cased letters in the given string to lowercase.

```
> lower("HELLO")
hello
```

regex applies a regular expression to a string and returns the matching substrings

```
> regex("^(?:(?P<scheme>[^:/?#]+):)?(?://(?P<authority>[^/?#]*))?", "https://terraform.io/docs/")
{
  "authority" = "terraform.io"
  "scheme" = "https"
}
```

regexall applies a regular expression to a string and returns a list of all matches

String Functions

replace searches a given string for another given substring, and replaces each occurrence with a given replacement string

```
> replace("hello world", "/w.*d/", "everybody")
hello everybody
```

split produces a list by dividing a given string at all occurrences of a given separator.

```
> split(",", "foo,bar,baz")
[
  "foo",
  "bar",
  "baz",
]
```

strrev reverses the characters in a string

```
> strrev("hello")
olleh
```

substr extracts a substring from a given string by offset and length

```
> substr("hello world", 1, 4)
ello
```

title converts the first letter of each word in the given string to uppercase

```
> title("hello world")
Hello World
```

trim removes the specified characters from the start and end of the given string

```
> trim("?!hello?!", "!?")
hello
```

String Functions

trimprefix removes the specified prefix from the start of the given string. If the string does not start with the prefix, the string is returned unchanged

```
> trimprefix("helloworld", "hello")
world
```

trimsuffix removes the specified suffix from the end of the given string

```
> trimsuffix("helloworld", "world")
hello
```

trimspace removes all types of whitespace from both the start and the end of a string

```
> trimspace("  hello\n\n")
hello
```

upper converts all cased letters in the given string to uppercase

```
> upper("hello")
HELLO
```

Collection Functions

alltrue returns true if all elements in a given collection are true or "true". It also returns true if the collection is empty.

```
> alltrue(["true", true])
true
> alltrue([true, false])
false
```

anytrue returns true if any element in a given collection is true or "true". It also returns false if the collection is empty

```
> anytrue(["true"])
true
> anytrue([true])
true
> anytrue([true, false])
true
> anytrue([])
false
```

chunklist splits a single list into fixed-size chunks, returning a list of lists

```
> chunklist(["a", "b", "c", "d", "e"], 2)
[
  [
    "a",
    "b",
  ],
  ...
```

```
> coalesce("a", "b")
a
> coalesce("", "b")
b
> coalesce(1,2)
1
```

coalesce takes any number of arguments and returns the first one that isn't null or an empty string

```
> coalescelist(["a", "b"], ["c", "d"])
[
  "a",
  "b",
]
```

coalescelist takes any number of list arguments and returns the first one that isn't empty

Collection Functions

compact takes a list of strings and returns a new list with any empty string elements removed

```
> compact(["a", "", "b", "c"])
[
  "a",
  "b",
  "c",
]
```

concat takes two or more lists and combines them into a single list

```
> concat(["a", ""], ["b", "c"])
[
  "a",
  "",
  "b",
  "c",
]
```

contains determines whether a given list or set contains a given single value as one of its elements

```
> contains(["a", "b", "c"], "a")
true
> contains(["a", "b", "c"], "d")
false
```

distinct takes a list and returns a new list with any duplicate elements removed

```
> distinct(["a", "b", "a", "c", "d", "b"])
[
  "a",
  "b",
  "c",
  "d",
]
```

Collection Functions

element retrieves a single element from a list

```
> element(["a", "b", "c"], 3)
a
```

Index finds the element index for a given value in a list

```
> index(["a", "b", "c"], "b")
1
```

flatten takes a list and replaces any elements that are lists with a flattened sequence of the list contents

```
> flatten([["a", "b"], []], ["c"])
["a", "b", "c"]
```

keys takes a map and returns a list containing the keys from that map

```
> keys({a=1, c=2, d=3})
[
  "a",
  "c",
  "d",
]
```

length determines the length of a given list, map, or string

```
> length([])
0
> length(["a", "b"])
2
> length({"a" = "b"})
1
> length("hello")
5
```

Collection Functions

Lookup retrieves the value of a single element from a map, given its key. If the given key does not exist, the given default value is returned instead.

```
> lookup({a="ay", b="bee"}, "a", "what?")
ay
> lookup({a="ay", b="bee"}, "c", "what?")
what?
```

Matchkeys constructs a new list by taking a subset of elements from one list whose indexes match the corresponding indexes of values in another list

```
> matchkeys(["i-123", "i-abc", "i-def"], ["us-west", "us-east", "us-east"], ["us-east"])
[
  "i-abc",
  "i-def",
]
```

Collection Functions

merge takes an arbitrary number of maps or objects, and returns a single map or object that contains a merged set of elements from all arguments

```
> merge({a="b", c="d"}, {e="f", c="z"})
{
  "a" = "b"
  "c" = "z"
  "e" = "f"
}
```

one takes a list, set, or tuple value with either zero or one elements. If the collection is empty, one returns null. Otherwise, one returns the first element. If there are two or more elements then one will return an error

```
> one([])
null
> one(["hello"])
"hello"
> one(["hello", "goodbye"])
Error: Invalid function argument
```

range generates a list of numbers using a start value, a limit value, and a step value

```
> range(3)
[
  0,
  1,
  2,
]
```

reserve takes a sequence and produces a new sequence of the same length with all of the same elements as the given sequence but in reverse order

```
> reverse([1, 2, 3])
[
  3,
  2,
  1,
]
```

Collection Functions

setintersection function takes multiple sets and produces a single set containing only the elements that all of the given sets have in common. In other words, it computes the intersection of the sets

```
> setintersection(["a", "b"], ["b", "c"], ["b", "d"])
[
  "b",
]
```

setproduct function finds all of the possible combinations of elements from all of the given sets by computing the Cartesian product.

```
> setproduct(["development", "staging", "production"], ["app1", "app2"])
[
  [
    "development",
    "app1",
  ],
  [
    "development",
    "app2",
  ],
  ...
```

Setsubtract function returns a new set containing the elements from the first set that are not present in the second set. In other words, it computes the relative complement of the first set in the second set

```
> setsubtract(["a", "b", "c"], ["a", "c"])
[
  "b",
]
```

Collection Functions

setunion function takes multiple sets and produces a single set containing the elements from all of the given sets. In other words, it computes the union of the sets

```
> setunion(["a", "b"], ["b", "c"], ["d"])
[
  "d",
  "b",
  "c",
  "a",
]
```

slice extracts some consecutive elements from within a list

```
> slice(["a", "b", "c", "d"], 1, 3)
[
  "b",
  "c",
]
```

sort takes a list of strings and returns a new list with those strings sorted lexicographically

```
> sort(["e", "d", "a", "x"])
[
  "a",
  "d",
  "e",
  "x",
]
```

Collection Functions

sum takes a list or set of numbers and returns the sum of those numbers

```
> sum([10, 13, 6, 4.5])
33.5
```

transpose takes a map of lists of strings and swaps the keys and values to produce a new map of lists of strings

```
> transpose({"a" = ["1", "2"], "b" = ["2", "3"]})
{
  "1" = [
    "a",
  ],
  "2" = [
    "a",
    "b",
  ],
  ...
```

values takes a map and returns a list containing the values of the elements in that map

```
> values({a=3, c=2, d=1})
[
  3,
  2,
  1,
]
```

zipmap constructs a map from a list of keys and a corresponding list of values

```
> zipmap(["a", "b"], [1, 2])
{
  "a" = 1,
  "b" = 2,
}
```

Encoding and Decoding Functions

Functions that will **encode** and **decode** for various formats

```
> base64encode("Hello World")
SGVsbG8gV29ybGQ=
```

```
> base64decode("SGVsbG8gV29ybGQ=")
Hello World
```

- base64encode
- jsonencode
- textencodebase64
- Yamlencode
- base64gzip
- **urlencode**

- base64decode
- csvdecode
- jsondecode
- textdecodebase64
- yamldecode

```
> urlencode("Hello World")
Hello%20World
> urlencode("🐻")
%E2%98%83
> "http://example.com/search?q=${urlencode("terraform urlencode")}"
http://example.com/search?q=terraform%20urlencode
```

Filesystem Functions

abspath takes a string containing a filesystem path and converts it to an absolute path. That is, if the path is not absolute, it will be joined with the current working directory

```
> abspath(path.root)
/home/user/some/terraform/root
```

dirname takes a string containing a filesystem path and removes the last portion from it.

```
> dirname("foo/bar/baz.txt")
foo/bar
```

pathexpand takes a filesystem path that might begin with a ~ segment, and if so it replaces that segment with the current user's home directory path

```
> pathexpand("~/.ssh/id_rsa")
/home/steve/.ssh/id_rsa
> pathexpand("/etc/resolv.conf")
/etc/resolv.conf
```

basename takes a string containing a filesystem path and removes all except the last portion from it

```
> basename("foo/bar/baz.txt")
baz.txt
```

Filesystem Functions

file reads the contents of a file at the given path and returns them as a string

```
> file("${path.module}/hello.txt")
Hello World
```

```
> fileexists("${path.module}/hello.txt")
true
```

fileexists determines whether a file exists at a given path

fileset enumerates a set of regular file names given a path and pattern

```
> fileset(path.module, "files/*.txt")
[
  "files/hello.txt",
  "files/world.txt",
]
```

filebase64 reads the contents of a file at the given path and returns them as a base64-encoded string

```
> filebase64("${path.module}/hello.txt")
SGVsbG8gV29ybGQ=
```

templatefile reads the file at the given path and renders its content as a template using a supplied set of template variables

```
%{ for addr in ip_addrs ~}
backend ${addr}:${port}
%{ endfor ~}
```

```
> templatefile("${path.module}/backends.tpl", { port = 8080, ip_addrs = ["10.0.0.1", "10.0.0.2"] })
backend 10.0.0.1:8080
backend 10.0.0.2:8080
```

Date and Time Functions

formatdate converts a timestamp into a different time format

```
> formatdate("DD MMM YYYY hh:mm ZZZ", "2018-01-02T23:12:01Z")
02 Jan 2018 23:12 UTC
> formatdate("EEEE, DD-MMM-YY hh:mm:ss ZZZ", "2018-01-02T23:12:01Z")
Tuesday, 02-Jan-18 23:12:01 UTC
> formatdate("EEE, DD MMM YYYY hh:mm:ss ZZZ", "2018-01-02T23:12:01-08:00")
Tue, 02 Jan 2018 23:12:01 -0800
> formatdate("MMM DD, YYYY", "2018-01-02T23:12:01Z")
Jan 02, 2018
> formatdate("HH:mmaa", "2018-01-02T23:12:01Z")
11:12pm
```

timeadd adds a duration to a timestamp, returning a new timestamp

```
> timeadd("2017-11-22T00:00:00Z", "10m")
2017-11-22T00:10:00Z
```

timestamp returns a UTC timestamp string in RFC 3339 format

```
> timestamp()
2018-05-13T07:44:12Z
```

Hash and Crypto Functions

Generate Hashes and cryptographic strings.

```
> bcrypt("hello world")
$2a$10$D5grTTzcsqyvAeIAnY/mYOIqliCoG7eAMX0/oFcuD.iErkksEbcA
```

- base64sha256
- base64sha512
- **bcrypt**
- filebase64sha256
- filebase64sha512
- filemd5
- filesha1
- filesha256
- filesha512
- **md5**
- rsadecrypt
- **sha1**
- sha256
- sha512
- **uuid**
- uuidv5

IP Network Functions

cidrhost calculates a full host IP address for a given host number within a given IP network address prefix

```
> cidrhost("10.12.127.0/20", 16)
10.12.112.16
> cidrhost("10.12.127.0/20", 268)
10.12.113.12
> cidrhost("fd00:fd12:3456:7890:00a2::/72", 34)
fd00:fd12:3456:7890::22
```

cidrnetmask converts an IPv4 address prefix given in CIDR notation into a subnet mask address

```
> cidrnetmask("172.16.0.0/12")
255.240.0.0
```

cidrsubnet calculates a subnet address within given IP network address prefix

```
> cidrsubnet("172.16.0.0/12", 4, 2)
172.18.0.0/16
> cidrsubnet("10.1.2.0/24", 4, 15)
10.1.2.240/28
> cidrsubnet("fd00:fd12:3456:7890::/56", 16, 162)
fd00:fd12:3456:7800:a200::/72
```

cidrsubnets calculates a sequence of consecutive IP address ranges within a particular CIDR prefix.

```
> cidrsubnets("10.1.0.0/16", 4, 4, 8, 4)
[
  "10.1.0.0/20",
  "10.1.16.0/20",
  "10.1.32.0/24",
  "10.1.48.0/20",
]
```

Type Conversion Functions

can evaluates the given expression and returns a boolean value indicating whether the expression produced a result without any errors

```
> can(local.foo.bar)
true
```

defaults a specialized function intended for use with input variables whose type constraints are object types or collections of object types that include optional attributes

nonsenstive takes a sensitive value and returns a copy of that value with the sensitive marking removed, thereby exposing the sensitive value

```
output "sensitive_example_hash" {
  value = nonsensitive(sha256(var.sensitive_example))
}
```

sensitive takes any value and returns a copy of it marked so that Terraform will treat it as sensitive, with the same meaning and behavior as for sensitive input variables.

```
locals {
  sensitive_content = sensitive(file("${path.module}/sensitive.txt"))
}
```

Type Conversion Functions

tobool converts its argument to a boolean value

```
tobool("true")
true
```

tolist converts its argument to a list value

```
> tolist(["a", "b", 3])
[
  "a",
  "b",
  "3",
]
```

tomap converts its argument to a map value

```
> tomap({"a" = 1, "b" = 2})
{
  "a" = 1
  "b" = 2
}
```

tonumber converts its argument to a number value

```
> tonumber("1")
1
```

toset converts its argument to a set value.

```
> toset(["a", "b", "c"])
[
  "a",
  "b",
  "c",
]
```

tostring converts its argument to a set value

```
> tostring(true)
"true"
```

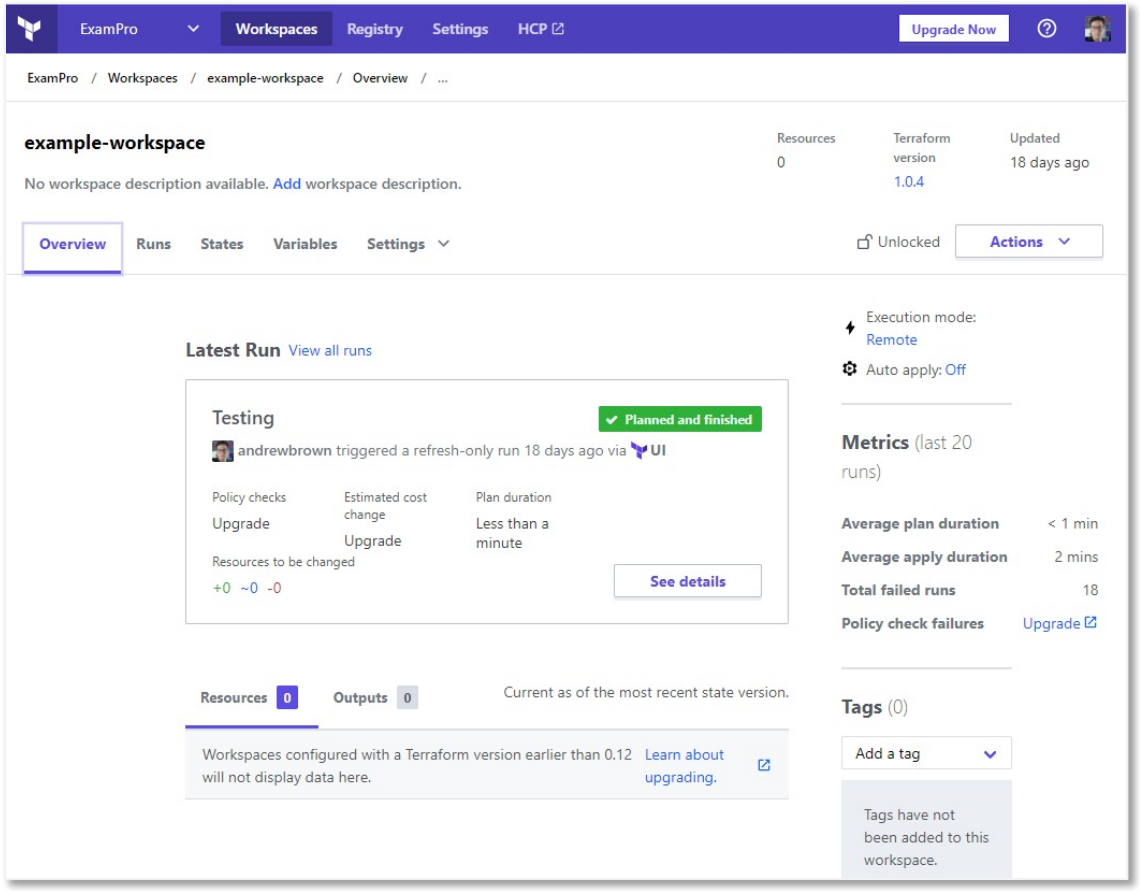
try evaluates all of its argument expressions in turn and returns the result of the first one that does not produce any errors

```
locals {
  example = try(
    [tostring(var.example)],
    tolist(var.example),
  )
}
```

Terraform Cloud

Terraform Cloud

Terraform Cloud is an application that helps teams use Terraform together.



Terraform Cloud features:

- Manages your state files
- History of previous runs
- History of previous states
- Easy and secure variable injection
- Tagging
- Run Triggers (chaining workspaces)
- Specify any version of terraform per workspace
- Global state sharing
- Commenting on Runs
- Notifications via Webhooks, Email, Slack
- Organization and Workspace Level Permissions
- Policy as Code (via Sentinel Policy Sets)
- MFA,
- Single Sign On (SSO) (at Business tier)
- Cost Estimation (at Teams and Governance Tier)
- Integrations with ServiceNow, Splunk, K8, and custom Run Tasks

Terraform Cloud is available as a hosted service at app.terraform.io

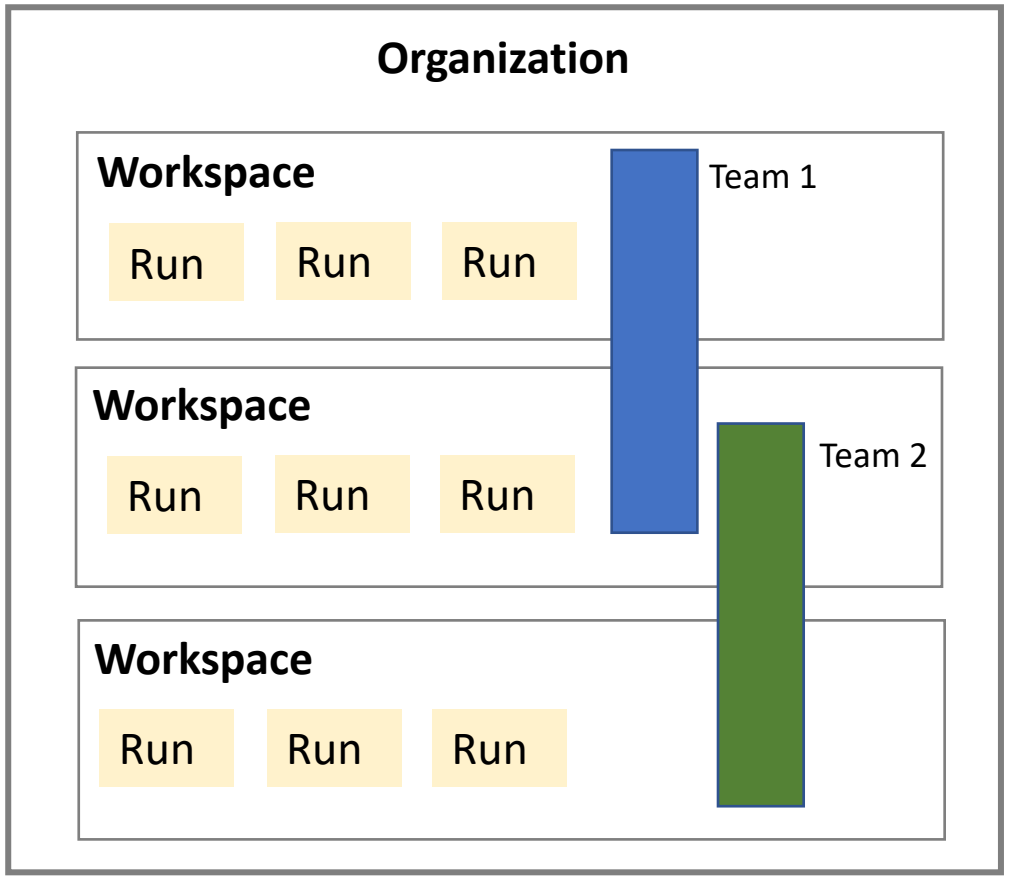
Terraform Cloud – Terms

Organizations
An organization is a collection of workspaces

Workspaces
A workspace belongs to an organization
A workspace represents a unique environment or stack.

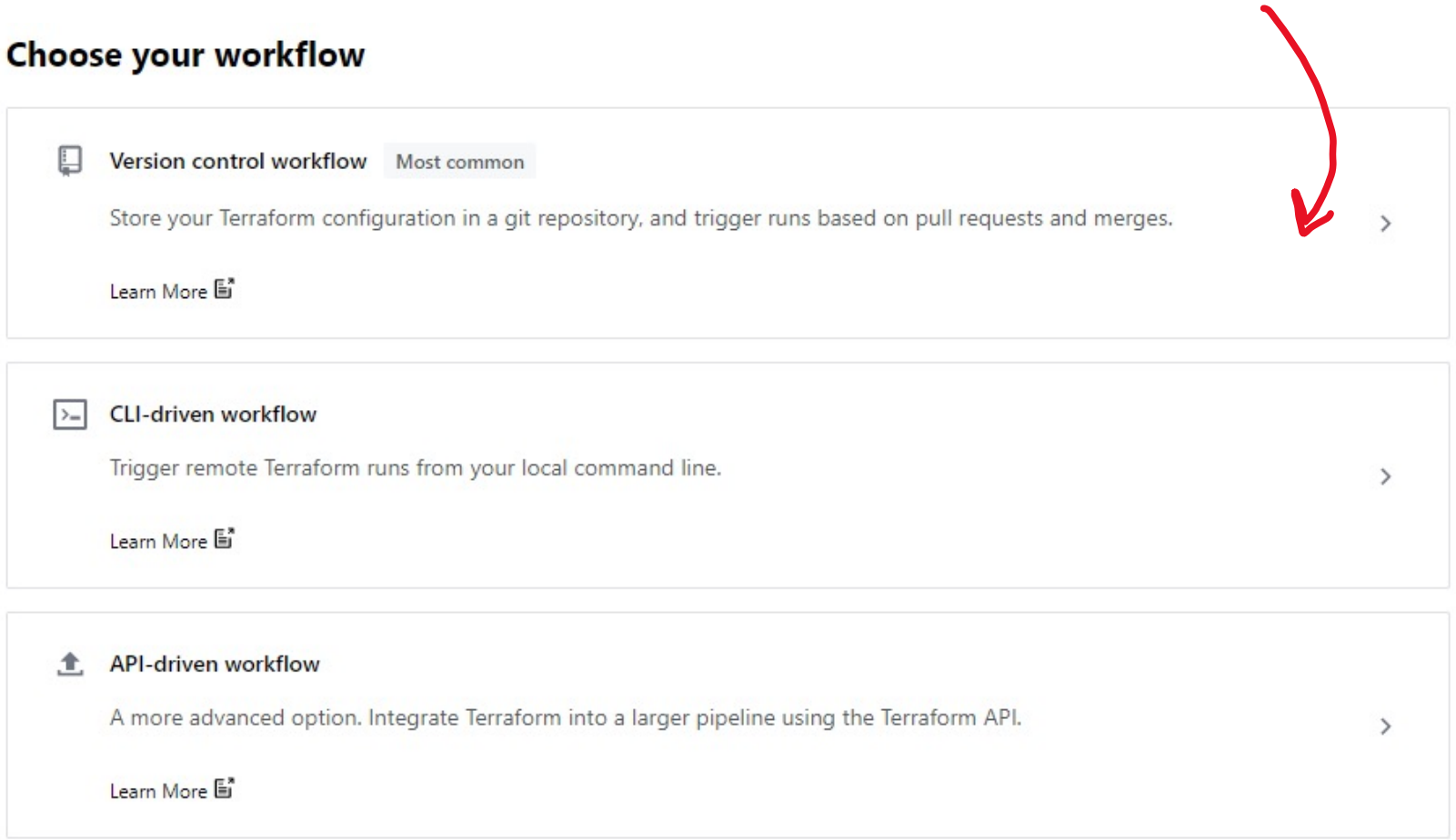
Teams
A team is composed of multiple members (users).
A team can be assigned to workspaces

Runs
A run represents a single-run of the terraform run environment that is operating on a execution plan.
Runs can be UI/VCS driven API driven or CLI driven



Terraform Cloud Run Workflows

Terraform Cloud offers **3 types** of Cloud Run Workflows
When you create a workspace you have **to choose a workflow**



Terraform Cloud Run Workflows

Terraform Cloud offers **3 types** of Cloud Run Workflows

UI/VCS Driven (User Interface and Version Control System)
Terraform Cloud is integrated with a specific branch in your VCS eg. Github via webhooks.
Whenever pull requests are submitted for the branch speculative plans are generated
Whenever a merge occurs to that branch, than a run is triggered on Terraform Cloud

API-Driven (Application Programming Interface)
Workspaces are not directly associated with a VCS repo, and runs are not driven by webhooks on your VCS provider
A third-party tool or system will trigger runs via upload a configuration file via the Terraform Cloud API
The configuration file is a bash script that is packaged in an archive (.tar.gz). You are pushing a **Configuration Version**

CLI-Driven (Command Line Interface)
Runs are triggered by the user running terraform CLI commands e.g. terraform apply and plan locally on their own machine.

Terraform Cloud – Organization-Level Permissions

Organization-Level Permissions manage certain resources or settings **across an organization**

- **Manage Policies** - create, edit, and delete the organization's Sentinel policies
- **Manage Policy Overrides** - override soft-mandatory policy checks.
- **Manage Workspaces** - create and administrate all workspaces within the organization
- **Manage VCS Settings** - set of VCS providers and SSH keys available within the organization

Organization Owners

Every organization has organization owner(s).

This is a special role that has every available permission and some actions only available to owners:

- Publish private modules
- Invite users to organization
- Manage team membership
- View all secret teams
- Manage organization permissions
- Manage all organization settings
- Manage organization billing
- Delete organization
- Manage agent

Terraform Cloud - Workspace-Level Permissions

Workspace-Level Permissions manage resource and settings for a **specific workspace**

General Workspace Permissions

Granular permissions you can apply to a user via **custom workspace permissions**

- Read runs
- Queue plans
- Apply runs
- Lock and unlock workspaces
- Download sentinel mocks
- Read variable
- Read and write variables
- Read state outputs
- Read state versions
- Read and write state versions

Fixed Permission Sets

Premade permissions for quick assignment.

- **Read**
  - Read runs
  - Read variables
  - Read state versions
- **Plan**
  - Queue Plans
  - Read variables
  - Read state versions
- **Write**
  - Apply runs
  - Lock and unlock workspaces
  - Download Sentinel mocks
  - Read and write variables
  - Read and write state versions

Workspace Admins

A workspace admin is a special role that grants the all level of permissions and some workspace-admin-only permissions:

- Read and write workspace settings
- Set or remove workspace permissions of any team
- Delete workspace

Terraform Cloud – API Tokens

Terraform Cloud supports three types of API Tokens. User, Team and Organization Tokens.

Organization API Tokens

- Have permissions across the entire organization
- Each organization can have one valid API token at a time
- Only organization owners can generate or revoke an organization's token.
- Organization API tokens are designed for creating and configuring workspaces and teams.
    - Not recommended as an all-purpose interface to Terraform Cloud

Team API Tokens

- allow access to the workspaces that the team has access to, without being tied to any specific user
- Each team can have **one** valid API token at a time
- any member of a team can generate or revoke that team's token
- When a token is regenerated, the previous token immediately becomes invalid
- designed for performing API operations on workspaces.
- same access level to the workspaces the team has access to

User API Tokens

- Most flexible token type because they inherit permissions from the user they are associated with
- Could be for a real user or a machine user.

Terraform Cloud – API Tokens

Shoot video of documentation because Access levels is too hard to show

Terraform Cloud – Private Registry

Terraform Cloud allows you to **publish private modules** for your Organization within the **Terraform Cloud Private Registry**

Terraform Cloud's private module registry helps you share Terraform modules across your organization. It includes support for:

- module versioning
- a searchable and filterable list of available modules
- a configuration designer

All users in your organization can view your private module registry.

Authentication

You can use either a user token or a team token for authentication, but the type of token you choose may grant different permissions.

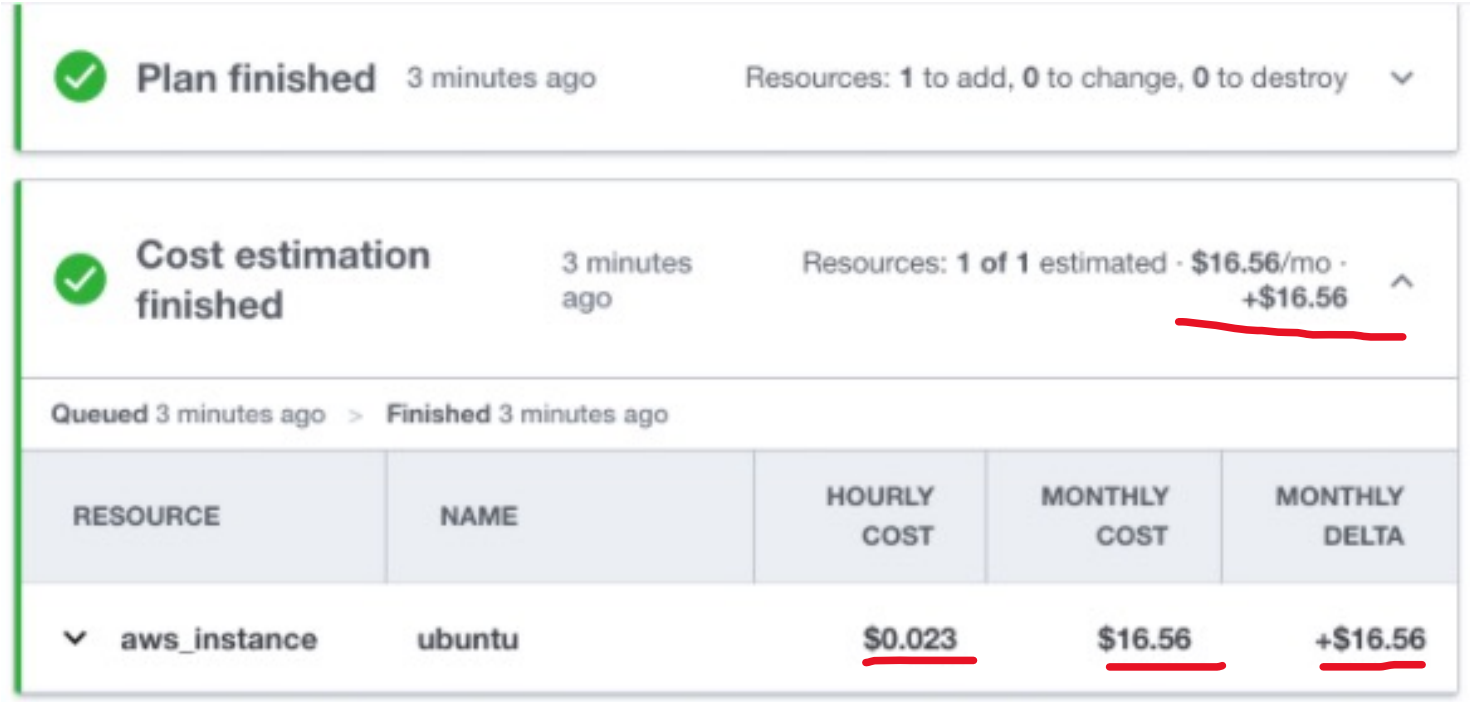
Using terraform login will obtain a user token

To use a team token you'll need to manually set it your terraform CLI configuration file

Terraform Cloud – Cost Estimation

Cost Estimation is a feature to get a monthly cost of resources display along side your runs.
Cost Estimation is available with Teams and Governance plan and above

Cost Estimation is only for specific cloud resources for AWS, Azure and GCP.



You can could use a Sentinel Policy to assert the expectation that resource are under a particular cost.

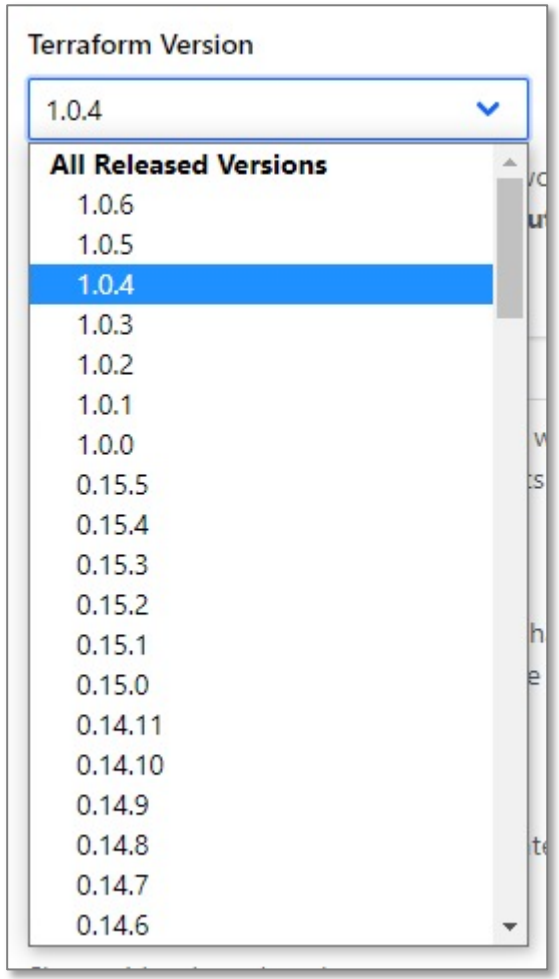
Terraform Cloud – Cost Estimation

Cost Estimation is only for specific cloud resources for AWS, Azure and GCP.

- aws_alb
- aws_autoscaling_group
- aws_cloudhsm_v2_hsm
- aws_cloudwatch_dashboard
- aws_cloudwatch_metric_alarm
- aws_db_instance
- aws_dynamodb_table
- aws_ebs_volume
- aws_elasticache_cluster
- aws_elasticsearch_domain
- aws_elb
- aws_instance
- aws_kms_key
- aws_lb
- aws_rds_cluster
- azurerm_app_service_custom_hostname_binding
- azurerm_app_service_environment
- azurerm_app_service_plan
- azurerm_app_service_virtual_network_swift_connection
- azurerm_cosmosdb_sql_database
- azurerm_databricks_workspace
- azurerm_firewall
- azurerm_hdinsight_hadoop_cluster
- azurerm_hdinsight_hbase_cluster
- azurerm_hdinsight_interactive_query_cluster
- azurerm_hdinsight_kafka_cluster
- azurerm_hdinsight_spark_cluster
- azurerm_integration_service_environment
- azurerm_linux_virtual_machine
- azurerm_linux_virtual_machine_scale_set
- azurerm_managed_disk
- azurerm_mariadb_server
- azurerm_mssql_elasticpool
- azurerm_mysql_server
- azurerm_postgresql_server
- azurerm_sql_database
- azurerm_virtual_machine
- azurerm_virtual_machine_scale_set
- azurerm_windows_virtual_machine
- azurerm_windows_virtual_machine_scale_set
- google_compute_disk
- google_compute_instance
- google_sql_database_instance

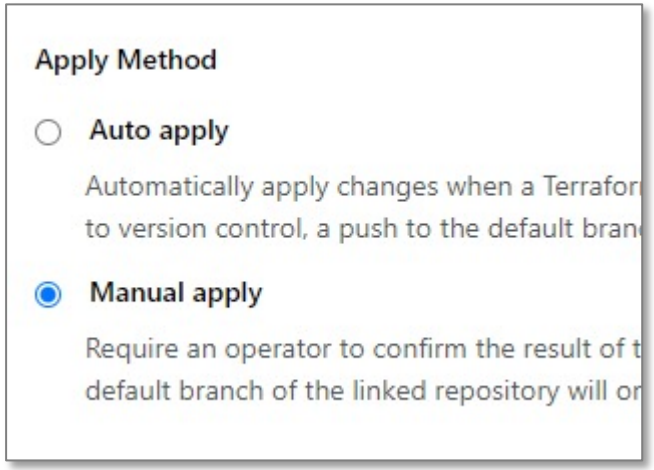
Terraform Cloud – Workflow Options

You can choose any version of Terraform for a Workspace



You can choose to share state globally across your organization

You can choose to auto approve runs (skip manual approval)



Migrating Default Local State

To migrate a local Terraform project that only uses the **default** workspace to Terraform Cloud

- Create a workspace in Terraform Cloud
- Replace your Terraform Configuration with **a remote backend**.

```
terraform {
}
```

```
terraform {
  backend "remote" {
    hostname = "app.terraform.io"
    organization = "my-org"

    workspaces {
      name = "my-workspace"
    }
  }
}
```

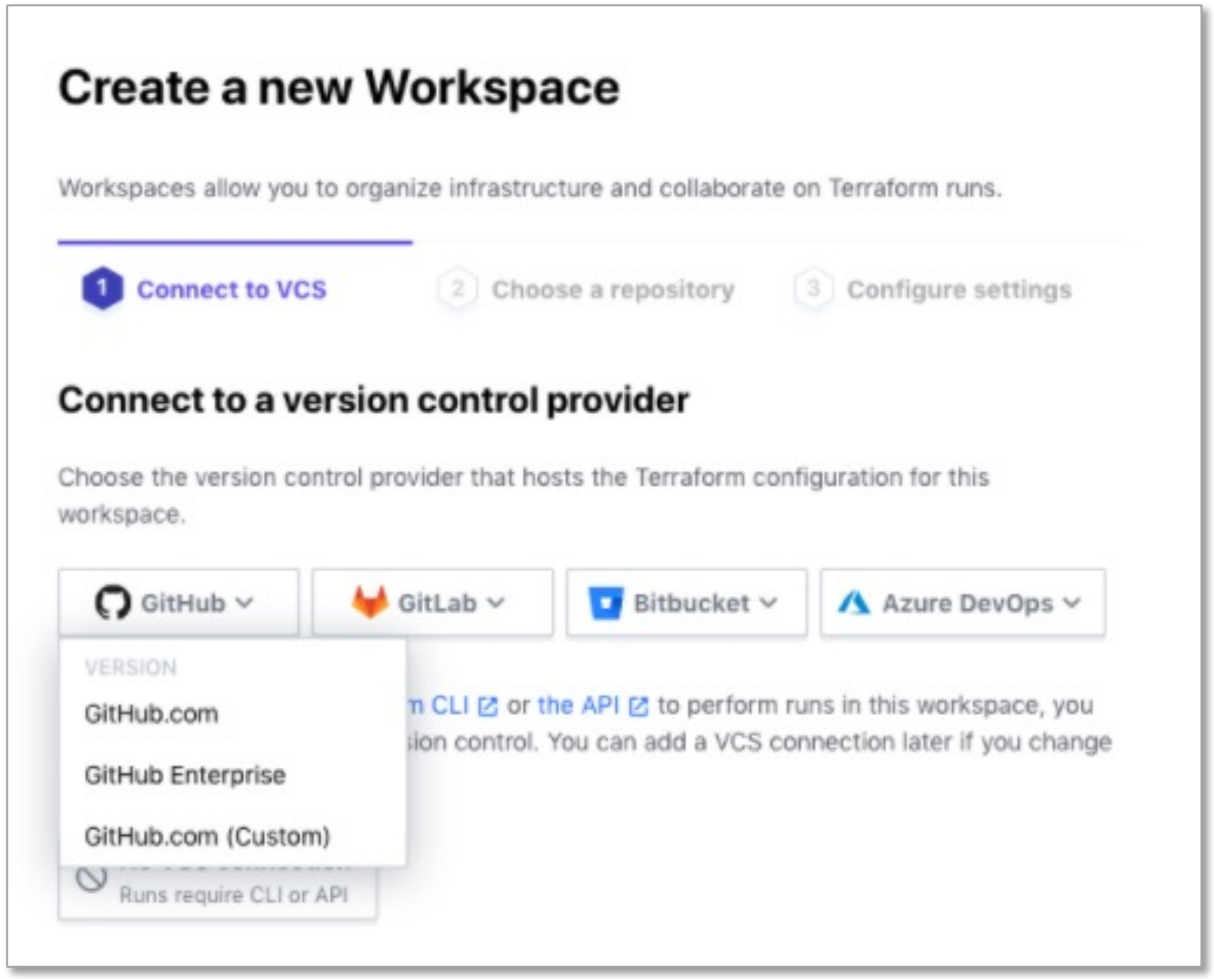
Run terraform init, and copy the existing state by typing **“yes”**

```
Do you want to copy existing state to the new backend?
  Pre-existing state was found while migrating the previous "local" backend to the
  newly configured "remote" backend. No existing state was found in the newly
  configured "remote" backend. Do you want to copy this state to the new "remote"
  backend? Enter "yes" to copy and "no" to start with an empty state.
```

Terraform Cloud VCS Integration

Terraform Cloud can integrate with the following Version Control Systems (VCS):

- Github
- Github (OAuth)
- Github Enterprise
- GitLab
- GitLab EE and CE
- Bitbucket Cloud
- Bitbucket Server and Data Center
- Azure DevOps Service
- Azure DevOps Server



Terraform Cloud Run Environment

When Terraform Cloud executes your terraform plan it runs them in its own Run Environment.

What is a Run Environment?
A run environment is Virtual Machine or container intended for the execution of code for specific runtime environment. A run environment is essentially a code build server.

The Terraform Cloud Run Environment is a **single-use Linux machine** running on the x86_64 architecture and the details of its internal implementation is not known.

Terraform Cloud will inject the following environment variables automatically on each run:

- **TFC_RUN_ID** - a unique identifier for this run (e.g. "run-CKuwsxMGgMd3W7Ui").
- **TFC_WORKSPACE_NAME** - name of the workspace used in this run
- **TFC_WORKSPACE_SLUG** - full slug of the configuration used in this run org/workspace eg. "acme-corp/prod-load-balancers".
- **TFC_CONFIGURATION_VERSION_GIT_BRANCH** - name of the branch used eg. “main”
- **TFC_CONFIGURATION_VERSION_GIT_COMMIT_SHA** - full commit hash of the commit used
- **TFC_CONFIGURATION_VERSION_GIT_TAG** - name of the git tag used eg. 1.1.0

These Env Vars can be accessed by defining a variable:

```
variable "TFC_RUN_ID" {}
```

Terraform Cloud Agents

Terraform Cloud Agents is a paid feature of the **Business** plan to allow Terraform Cloud to **communicate with isolated, private or on-premise infrastructure**.

This is useful for on-premise infrastructure types such as vSphere, Nutanix, or OpenStack

The agent architecture is pull-based, so no inbound connectivity is required
Any agent you provision will poll Terraform Cloud for work and carry out execution of that work locally.

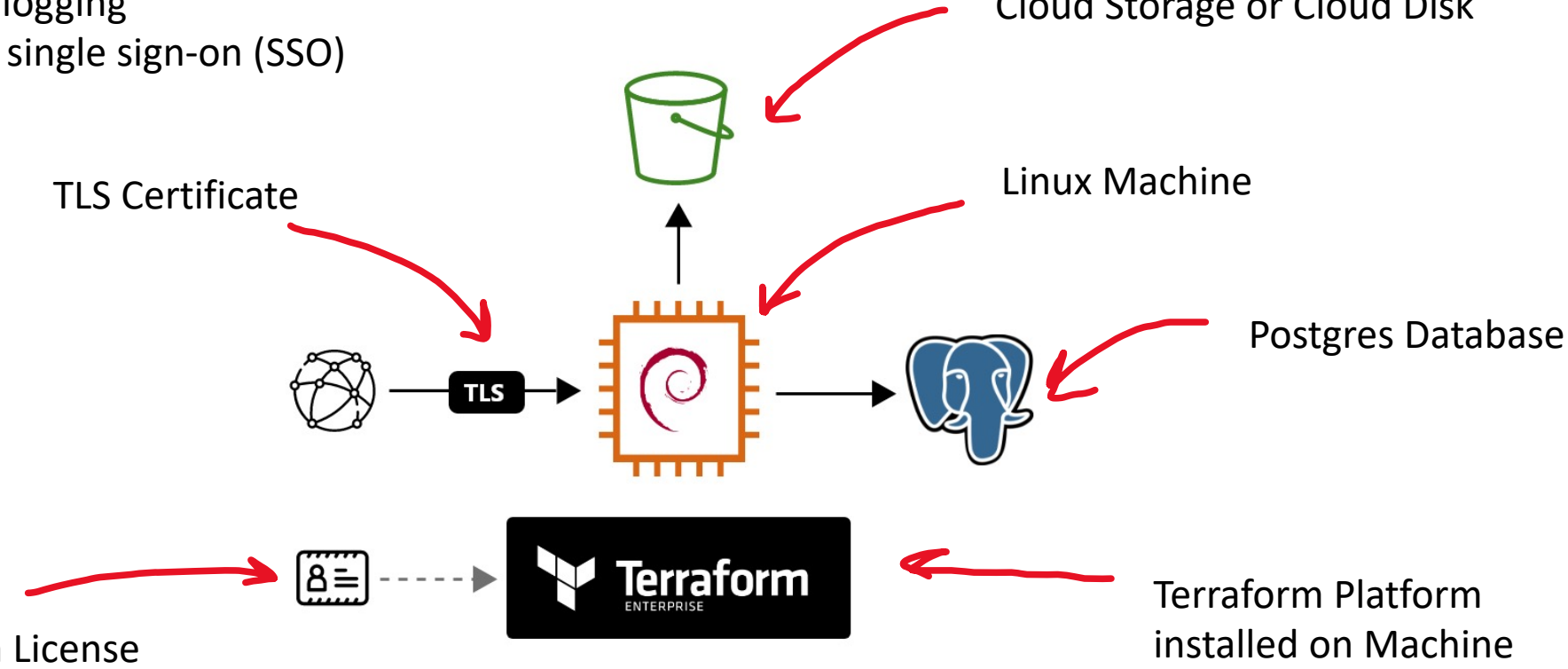
- Agents currently only support x86_64 bit Linux operating systems.
- You can also run the agent within Docker using the official Terraform Agent Docker container.
- Agents support Terraform versions 0.12 and above.
- System requires at least 4GB of free disk space (for temporary local copies) and 2 GB of memory
- Needs access to make outbound requests on HTTPS (TCP Port 443) to
  - App.terraform.io
  - Registry.terraform.io
  - Releases.hashicorp.com
  - archivist.terraform.io

Terraform Enterprise

Terraform Enterprise is our **self-hosted distribution** of Terraform Platform

Terraform Enterprise offers a private instance of the Terraform Platform application with benefits such as :

- no resource limits
- with additional enterprise-grade architectural features
  - Audit logging
  - SAML single sign-on (SSO)



Terraform Enterprise Requirements

Operational mode: - how data should be stored

- External Services
  - Postgres
  - and AWS S3 Bucket, GCP Cloud Storge Bucket or Azure Blob Storage or Minio Object Storage
- Mounted Disk – stores data in a separate directory on a host intended for an external disk e.g. EBS, iSCSI
- Demo – Stores all the data on the instance, data can be backed up with snapshots*, not recommend for production use*

Credentials – Ensure you have credentials to use Enterprise and have Secure connection

- Terraform Enterprise License – You obtain a license form HashiCorp
- TLS Certificate and Private Key – You need to prove you're your own TLS Certificate

Linux Instance – Terraform Enterprise is designed to run on Linux:

Supported OS

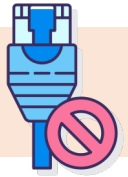
- Debian 7.7+
- Ubuntu 14.04.5 / 16.04 / 18.04 / 20.04
- Red Hat Enterprise Linux 7.4 - 7.9
- CentOS 7.4 - 7.9
- Amazon Linux 2014.03 / 2014.09 / 2015.03 / 2015.09 / 2016.03 / 2016.09 / 2017.03 / 2017.09 / 2018.03 / 2.0
- Oracle Linux 7.4 - 7.9

Hardware Requirements

- At least 10GB of disk space on the root volume
- At least 40GB of disk space for the Docker data directory (defaults to /var/lib/docker)
- At least 8GB of system memory
- At least 4 CPU cores

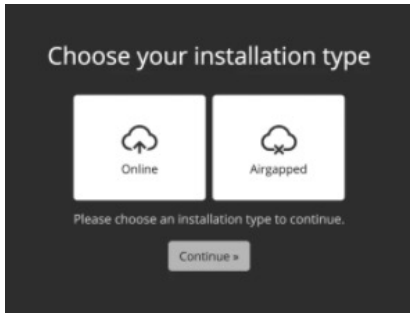
Air Gapped Environments

What is Air Gap?
Air Gap or disconnected network is a network security measure employed on one or more computers to ensure that a secure computer network is physically isolated from unsecure networks e.g. Public Internet



No internet. No outside connectivity

Industries in the **Public Sector** (e.g. government, military) or **large enterprise** e.g. Finance and Energy often employ air gap networks.



HashiCorp Terraform Enterprise **supports** an installation type for Air Gapped Environments

To install or update Terraform Enterprise you will supply an “air gap bundle” which is an archive of a Terraform Enterprise release version

Terraform Cloud Features and Pricing

Open-Source Software (OSS)	Cloud			Self-Hosted
	Free	Teams and Governance	Business	Enterprise (self-hosted)
IaC, Workspaces, Variables, Runs, Resource Graph, Providers, Modules, Public Module Registry				
	Remote State, VCS Connection, Workspace Mgmt., Secure Variable Storage, Remote Runs, Private Module Registry			
		Team Management, **Sentinel Policy as Code Management**, Cost Estimation		
			Single Sign On (SSO), Audit Logging	
			Self Hosted Agents	
			Configuration Designer, ServiceNow Integration	
	1 Current Runs	2 Current Runs	Unlimited Current Runs	
Local CLI	Cloud			Private
Community		Bronze	Silver, Gold	
	$0 up to 5 users	Starting at $20 user/month	Contact Sales	Contact Sales

Workspaces

Workplaces allows you to manage multiple environments or alternate state files.
eg. Development, Production

There are two variants of workspaces:

- CLI Workspaces – A way of managing alternate state files (locally or via remote backeneds)
- Terraform Cloud Workspaces – acts like completely separate working directories

Think of workspaces as being similar to having different branches in a git repository
Workspaces are technically equivalent to renaming your state file

In Terraform is 0.9 used to called workspaces "environments"

By default, you already have a single workspace in your local backend called **default**

```
terraform workspace list
* default
```

The default workspace can never be deleted

Workspace Internals

Depending if you a local or remote backend changes how the state file is stored

Local State	Remote State
Terraform stores the workspace states in a folder called **terraform.tfstate.d**	The workspace files are stored directly in the configured backend.
In practice individuals or very small teams will have been known to commit these files to their repositories.	

using a remote backend instead is recommended when there are multiple collaborators

Current Workspace Interpolation

You can reference the current workspace name via **terraform.workspace**

```
resource "aws_instance" "example" {
  count = "${terraform.workspace == "default" ? 5 : 1}"

  # ... other arguments
}
```

```
resource "aws_instance" "example" {
  tags = {
    Name = "web - ${terraform.workspace}"
  }
  # ... other arguments
}
```

Multiple Workspaces

A Terraform configuration has a backend that:

- defines **how operations are executed**
- where **persistent data is stored** e.g. Terraform State

Multiple workspaces are currently supported by the following backends

- AzureRM
- Consul
- COS
- GCS
- Kubernetes
- Local
- Manta
- Postgres
- Remote
- S3

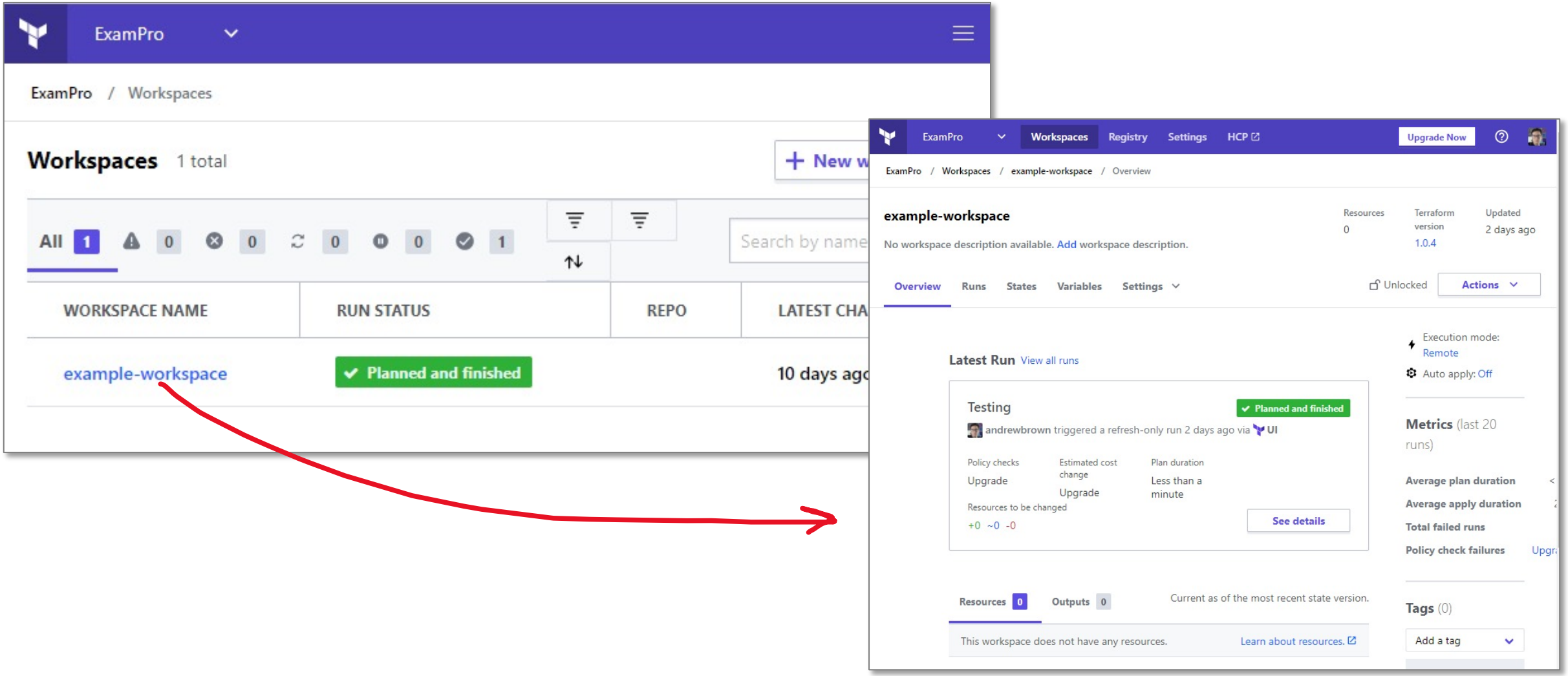
Certain backends support *multiple* named workspaces

- allowing multiple states to be associated with a single configuration.

The configuration still has only one backend, but multiple distinct instances of that configuration to be deployed without configuring a new backend or changing authentication credentials.

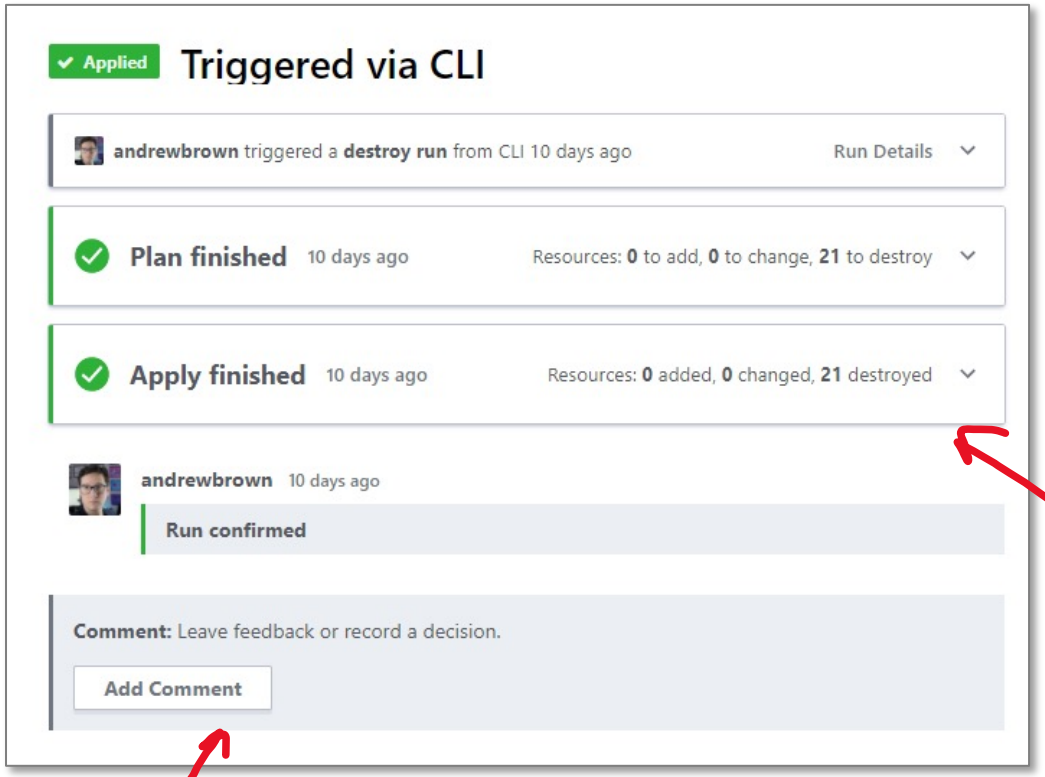
Terraform Cloud Workspaces

You can create Workspaces on Terraform Cloud

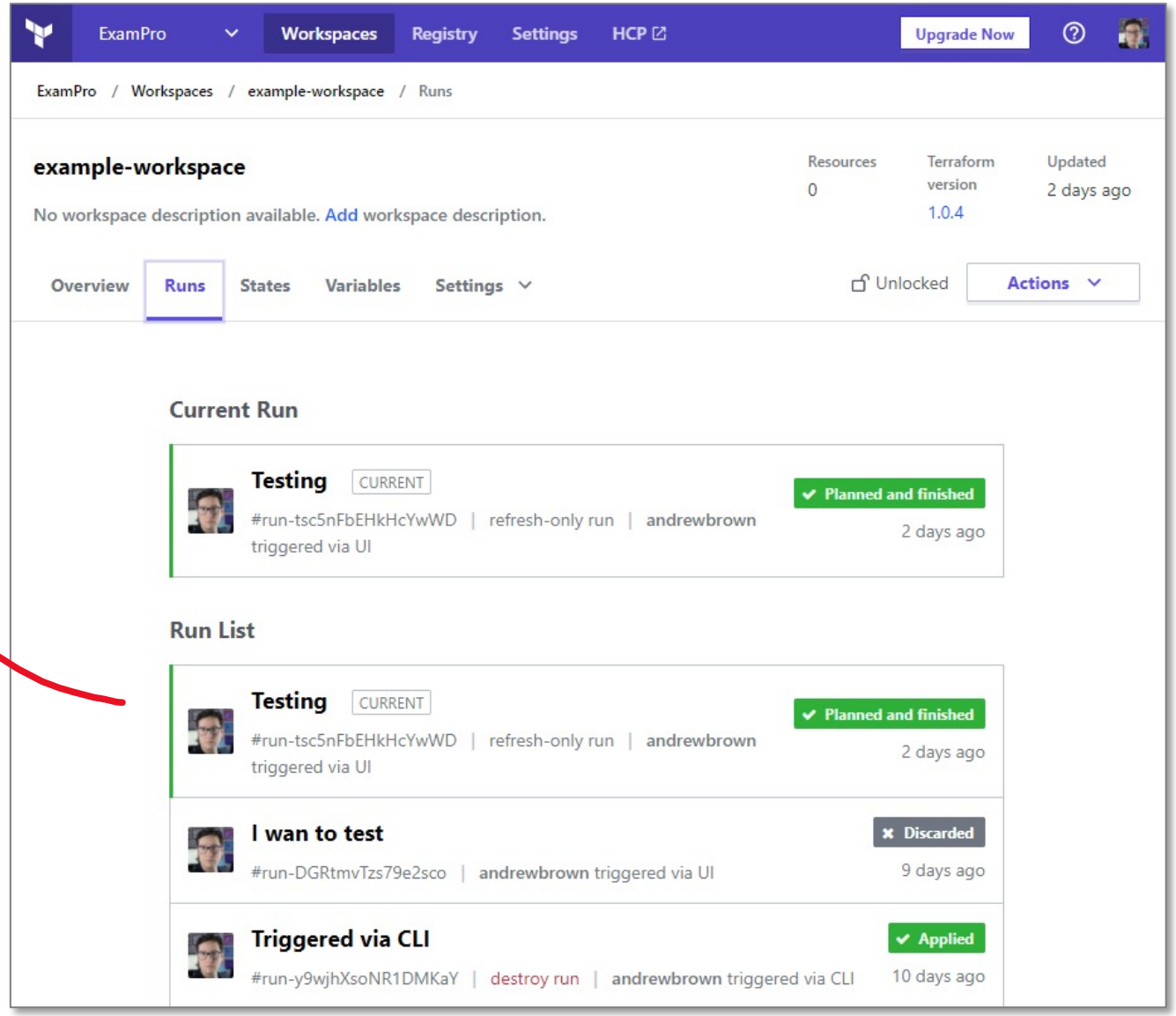


Terraform Cloud Workspaces

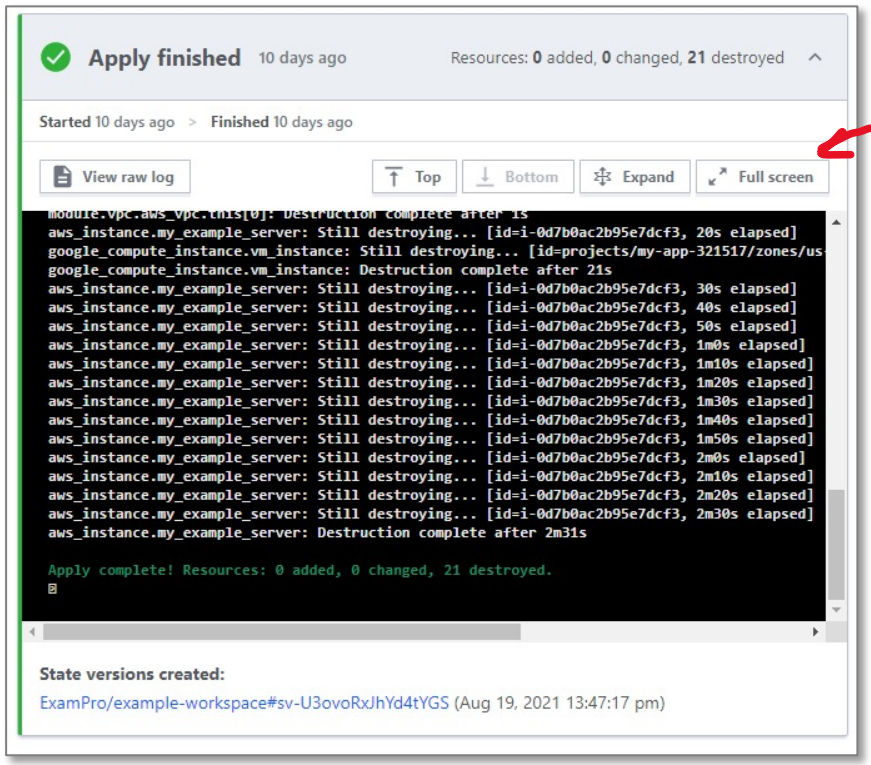
You can see a history of previous runs.

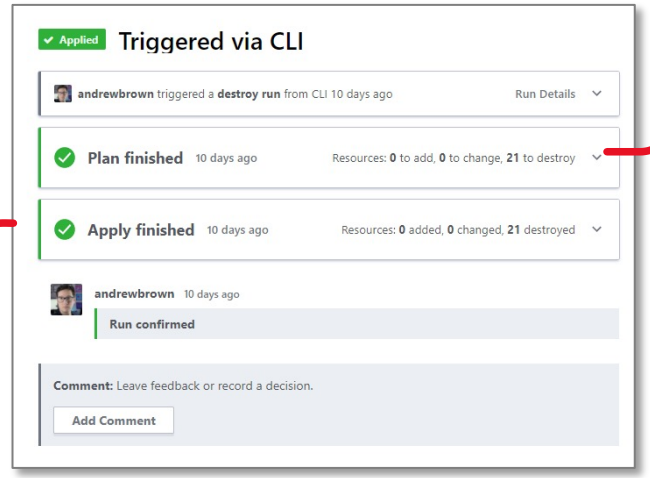


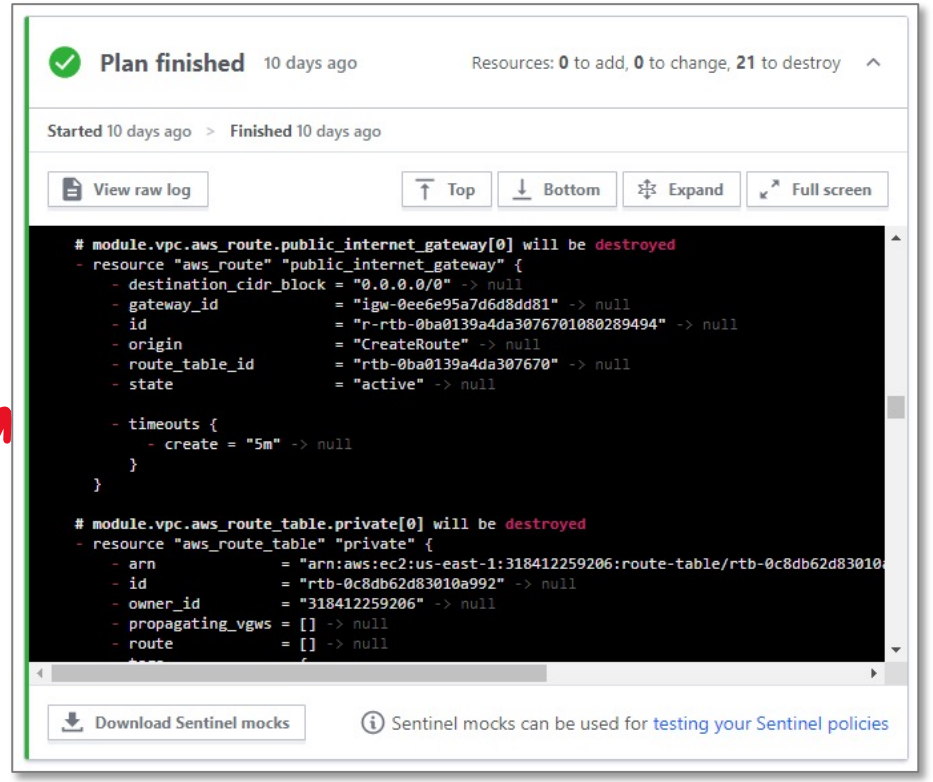
Comment on each run



Terraform Cloud Workspaces



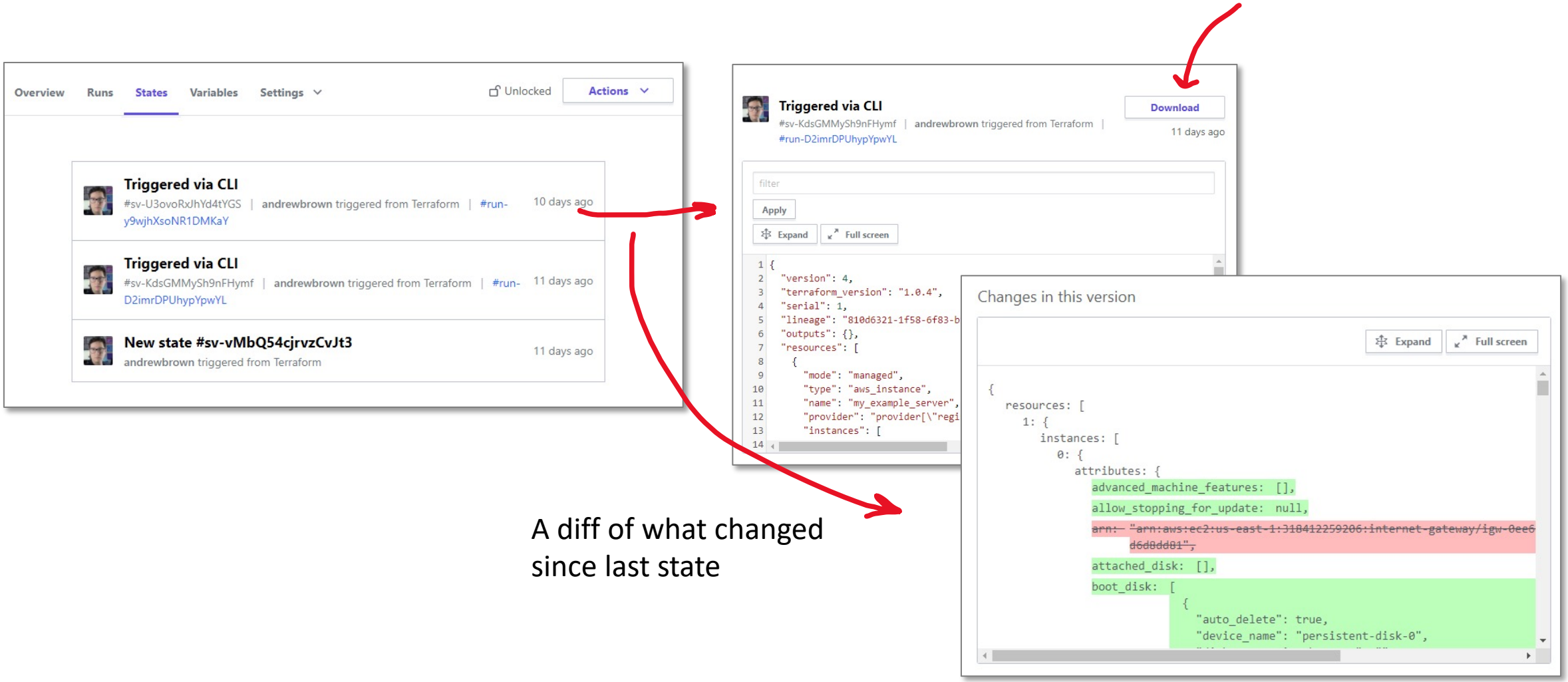




Terraform Cloud Workspaces

You can see a history of previously held states (snapshots)

Download the state file



A diff of what changed since last state

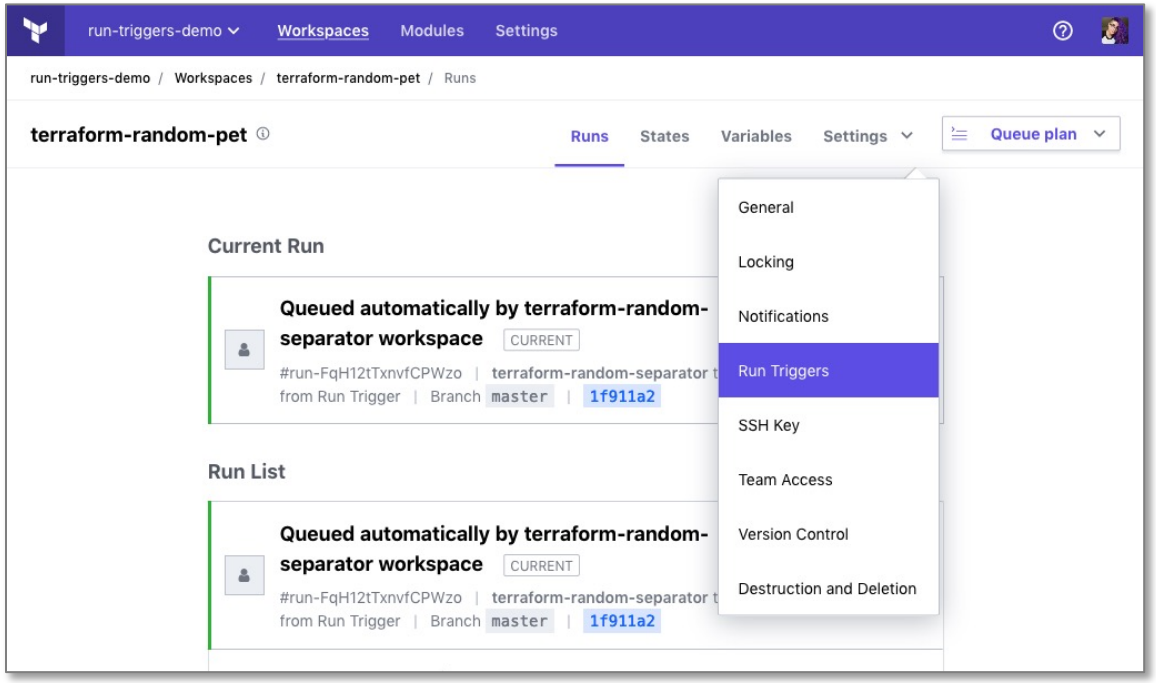
Terraform Cloud Run Triggers

Terraform Cloud provides a way to **connect your workspace to one or more workspaces** via **Run Triggers** within your organization, known as "source workspaces".

Run Triggers
allow runs to queue automatically in your workspace on successful apply of runs in any of the source workspaces. You can connect each workspace to up to 20 source workspaces.

Run triggers are designed for workspaces that rely on information or infrastructure produced by other workspaces.

If a Terraform configuration uses data sources to read values that might be changed by another workspace, run triggers let you explicitly specify that external dependency.



terraform workspace

terraform workspace **list**

list all existing workspaces
current workspace is indicated using an asterisk (*)

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

terraform workspace **show**

Show the current

```
$ terraform workspace show
development
```

terraform workspace **select**

Switch to target workspace

```
$ terraform workspace select default
Switched to workspace "default"
```

terraform workspace **new**

Create and **switch** to workspace

```
$ terraform workspace new example
Created and switched to workspace "example"
```

terraform workspace **delete**

Delete target workspace

```
$ terraform workspace delete example
Deleted workspace "example"
```

Workspaces Differences

Terraform Cloud workspaces and local working directories serve the same purpose, but they store their data differently:

Component	Local Terraform	Terraform Cloud
Terraform configuration	On disk	In linked version control repository, or periodically uploaded via API/CLI
Variable values	As .tfvars files, as CLI arguments, or in shell environment	In workspace
State	On disk or in remote backend	In workspace
Credentials and secrets	In shell environment or entered at prompts	In workspace, stored as sensitive variables

Sentinel

Sentinel is an embedded **policy-as-code framework** integrated with the Terraform Platform

What is Policy as Code?
When you write code to automate regulatory or governance policies

Features of Sentinel:

Embedded - enable policy enforcement in the data path to actively reject violating behavior instead of passively detecting.

Fine-grained, condition-based policy - Make policy decisions based on the condition of other values

Multiple Enforcement Levels - Advisory, soft and hard-mandatory levels allow policy writers to warn on or reject behaviour

External Information - Source external information to make holistic policy decisions

Multi-Cloud Compatible - Ensure infrastructure changes are within business and regulatory policy across multiple providers

Sentinel is a paid service part of
Team & Governance upgrade package

Policy as Code

Sentinel is built around the idea and provides all the benefits of policy as code

Benefits of Policy as Code

- **Sandboxing** – The ability to create guardrails to avoid dangerous actions or remove the need of manual verification
- **Codification** – The policies are well documented and exactly represent what is enforced
- **Version Control** – Easy to modify or iterate on policies, with a chain of history of changes over time
- **Testing** - syntax and behavior can be easily validated with Sentinel, ensuring policies are configured as expected
- **Automation** – policies existing as code allows you direct integrate policies in various systems to auto-remediate, notify.

Sentinel and Policy as Code

- **Language** - All Sentinel policies are written using the Sentinel language
  - Designed to be non-programmer and programmer friendly, embeddable and safe.
- **Development** - Sentinel provides a CLI for development and testing.
- **Testing** - Sentinel provides a test framework designed specifically for automation.

Sentinel Policy Language Example

Examples of policies you can write and enforce for various providers

AWS
- Restrict owners of the aws_ami data source
- Enforce mandatory tags on taggable AWS resources
- Restrict availability zones used by EC2 instances
- Disallow 0.0.0.0/0 CIDR block in security groups
- Restrict instance types of EC2 instances
- Require S3 buckets to be private and encrypted by KMS keys
- Require VPCs to have DNS hostnames enabled

Google Cloud Platform
- Enforce mandatory labels on VMs
- Disallow 0.0.0.0/0 CIDR block in network firewalls
- Enforce limits on GKE clusters
- Restrict machine type of VMs

VMWare
- Require Storage DRS on datastore clusters
- Restrict size and type of virtual disks
- Restrict CPU count and memory of VMs
- Restrict size of VM disks
- Require NFS 4.1 and Kerberos on NAS datastores

Azure
- Enforce mandatory tags of VMs
- Restrict publishers of VMs
- Restrict VM images
- Restrict the size of Azure VMs
- Enforce limits on AKS clusters
- Restrict CIDR blocks of security groups

Cloud-Agnostic
- Allowed providers
- Prohibited providers
- Limit proposed monthly costs
- Prevent providers in non-root modules
- Require all modules have version constraints
- Require all resources be created in modules in a private module registry
- Use most recent versions of modules in a private module registry

Sentinel Policy Language Example

Example of Sentient Policy that restricts the Availability Zones for EC2 instances on AWS

Import policy language functions

Specify AZs

Get all VMs

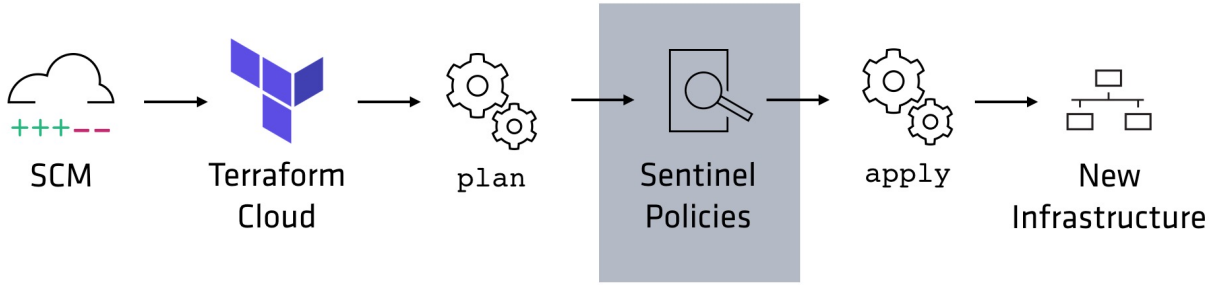
Filter that restricts AZ use for VMs

Define the rule

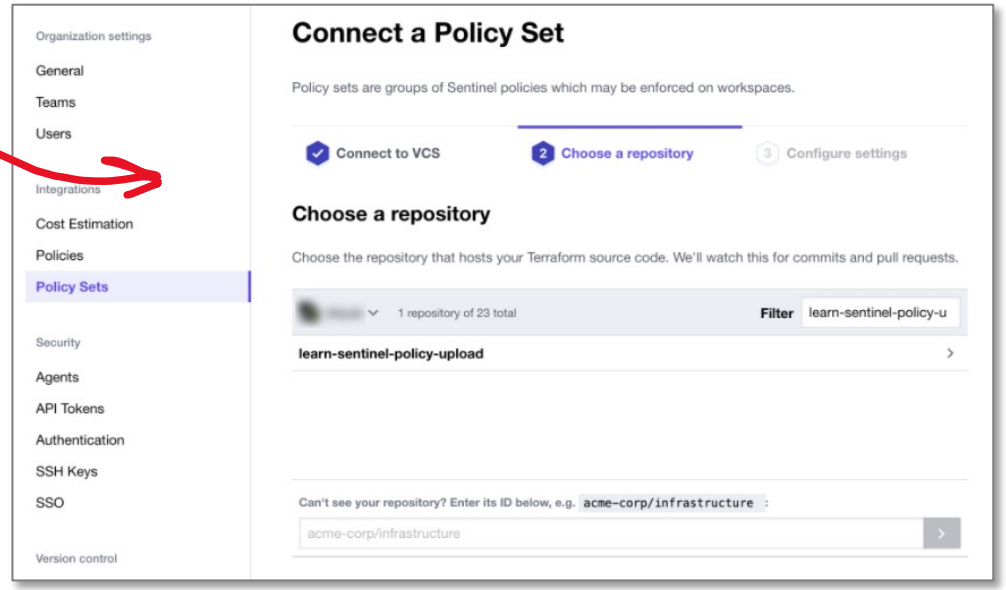
```
import "tfplan-functions" as plan

# Allowed EC2 Zones
# Include "null" to allow missing or computed values
allowed_zones = [
  "us-east-1a","us-east-1b","us-east-1c","us-east-1d","us-east-1e","us-east-1f",
]

# Get all EC2 instances
allEC2Instances = plan.find_resources("aws_instance")

# Filter to EC2 instances with violations
# Warnings will be printed for all violations since the last parameter is true
violatingEC2Instances = plan.filter_attribute_not_in_list(allEC2Instances,
                        "availability_zone", allowed_zones, true)

# Main rule
main = rule {
  length(violatingEC2Instances["messages"]) is 0
}
```

Sentinel with Terraform

Sentinel can be *integrated* with Terraform via Terraform Cloud as part of your IaC provisioning pipeline.



Within Terraform Cloud you can **create a Policy Set** and apply these to and the apply a Policy Set to a Terraform Cloud Workspace



Hashicorp Packer

Packer is a developer tool to **provision a build image** that will be stored in a repository.
Using a build image before you deploy provides:

- immutable infrastructure
- your VMs in your fleet are all one-to-one in configuration
- Faster deploys for multiple servers after each build
- Earlier detection and intervention of package changes or deprecation of old technology

Packer configures a machine via a Packer Template

- Packer Templates use the HashiCorp Configuration Language (HCL)

Packer Template File

Packer configures a machine or container via a **Packer Template**

- Packer Templates use the HashiCorp Configuration Language (HCL)

The **source** says *where* and what kind of image to build

In this case it will create an **EBS-backed AMI**
The image will be stored directly in AWS under EC2 Images

The **build** allows us to provide configuration scripts.
Packer supports a wide range of **provisioners**:

- Chef, Puppet, Ansible, PowerShell, Bash, Salt….

Post-provisioners run after the image is built.
They can be used to upload artifacts or re-package

```
variable "ami_id" {
  type    = string
  default = "ami-01e78c5619c5e68b4"
}

locals {
    app_name = "httpd"
}

source "amazon-ebs" "httpd" {
  ami_name      = "my-server-${local.app_name}"
  instance_type = "t2.micro"
  region        = "us-west-2"
  source_ami    = "${var.ami_id}"
  ssh_username  = "ec2-user"
  tags = {
    Env  = "DEMO"
    Name = "Pmy-server--${local.app_name}"
  }
}

build {
  sources = ["source.amazon-ebs.httpd"]

  provisioner "shell" {
    script = "script/script.sh"
  }

  post-processor "shell-local" {
    inline = ["echo foo"]
  }
}
```

Terraform and Packer Integration

To integrate packer there two steps:

1. Building the image:

Packer is not a service but a development tool so you need to manually run packer or automate the building of images with a build server running packer

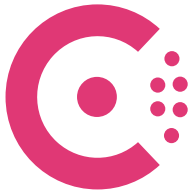
2. Referencing the Image:

Once an image is built you can reference the image as a **Data Source**

eg. for AWS AMI we can ask it to match on regex and to select the most recent

```
data "aws_ami" "example" {
  executable_users = ["self"]
  most_recent      = true
  name_regex       = "^myami-\\d{3}"
  owners           = ["self"]
}
```

Terraform and Consul



Consul is a **service networking platform** which provides:

- **service discovery** – central registry for services in the network
  - Allows for direct communication, no single-point of failure via load balancers
- **service mesh** – managing network traffic between services
  - A communication layer on top of your container application, *think middleware*
- **application configuration capabilities**

Consul is useful when you have a micro-service or **service-oriented architecture** with **hundred or thousands of services** (containerized apps or workloads)

Consul integrates with Terraform in the following ways:

- Remote backend
  - Consul has a Key Value (KV) Store to store configurations
- Consul Provider

HashiCorp Vault

What is HashiCorp Vault?

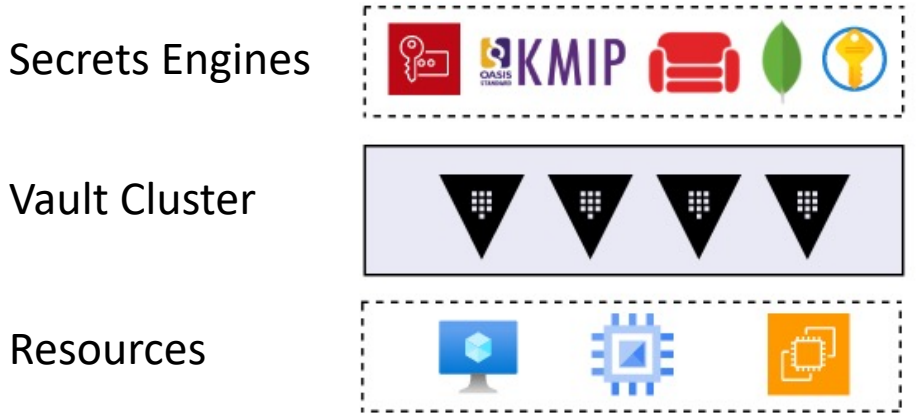
Vault is a tool for **securely accessing secrets** from multiple secrets data stores.

Vault is deployed to a server where:

- Vault Admins can directly manage secrets
- Operators (developers) can access secrets via an API

Vault provides a unified interface:

- to any secret
  - AWS Secrets, Consul Key Value, Google Cloud KMS, Azure Service principles….
- providing tight access control
  - Just-in-Time (JIT) - reducing surface attack based on range of time
  - Just Enough Privilege (JeP) - reducing service attack by providing least-permissive permissions
- recording a detailed audit log – tamper evidence



Vault is deploy to Virtual Machines in a cluster.
Vaults can be backed up into snapshots

Terraform and Vault

When a developer is working with Terraform and they need to deploy to a provider eg. AWS, they will need AWS credentials

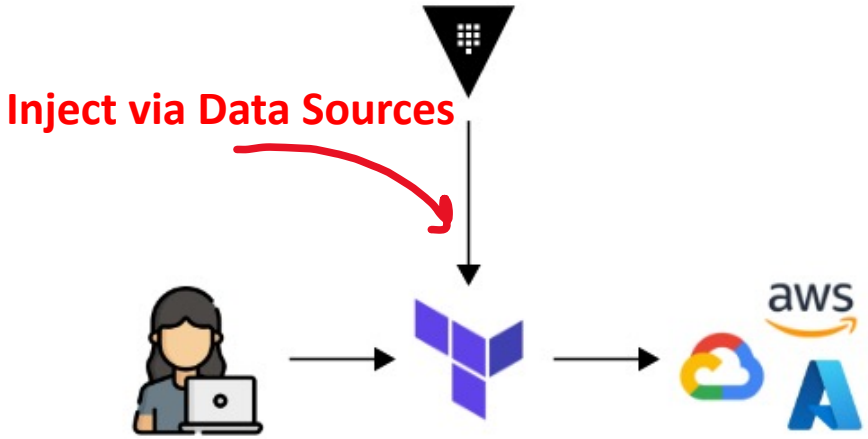
AWS Credentials are long-lived, meaning a user generates a key and secret, and they are usable until they are deleted.

The AWS Credentials reside on the developer's local machine, and so that machine is at risk of being compromised by a malicious actors looking to steal the credentials.

If we could:

- provide credentials Just-In-Time (JIT)
- expire the credentials after a short amount of time (short-lived)

we can reduce the attack surface area of the local machine.



Vault can be used to **inject** *short-lived* secrets at the time of terraform apply

Vault Injection via Data Source

A vault server is provisioned
A vault engine is configured e.g. AWS Secret Engine
Vault will create a machine user for AWS
Vault will generate short-live AWS credentials from that machine user
Vault will manage and apply the AWS Policy

Within our Terraform we can provide a Data Source to Vault

```
data "vault_aws_access_credentials" "creds" {
  backend = data.terraform_remote_state.admin.outputs.backend
  role    = data.terraform_remote_state.admin.outputs.role
}

provider "aws" {
  region     = var.region
  access_key = data.vault_aws_access_credentials.creds.access_key
  secret_key = data.vault_aws_access_credentials.creds.secret_key
}
```

When Terraform Apply is run, it will pull short –lived credentials to be used scope for the duration of the current run.

Everytime you run apply you will get new short-lived credentials.

Gruntwork

Gruntwork is a software company that builds DevOps tools **that extends or leverages Terraform**

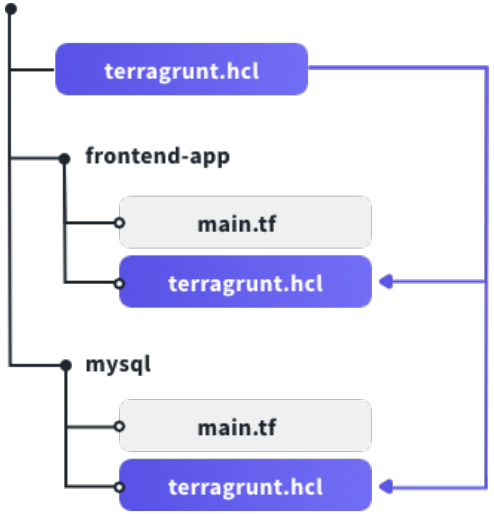
- **Infrastructure as Code Library** - 300,000 lines of reusable, battle-tested, production-ready infrastructure code for AWS, GCP, and Azure, bash scripts, Go programs, and other tools
- **Terragrunt -** a thin wrapper that provides extra tools for keeping your configurations DRY, working with multiple Terraform modules, and managing remote state
- **TerraTest** – a testing framework for Infrastructure provisioned with Terraform.
- **Gruntwork Landing Zone for AWS** – a collection of baselines for multi-account security on AWS
- **Gruntwork Pipelines** - security-first approach to a CI/CD pipeline for infrastructure
- **Gruntwork Reference Architecture** - opinionated, battle-tested, best-practices way to assemble the code from the Infrastructure as Code Library

Terragrunt

Terragrunt is a thin wrapper for Terraform that provides extra tools for:

- keeping your configurations **DRY**
- working with multiple Terraform modules
- managing remote state.

https://terragrunt.gruntwork.io



Don't-Repeat-Yourself (DRY) is a **programming methodology** to abstract repeated code into function, modules or libraries and often in **isolate files** to reduce code complexity effort and errors.

Terragrunt

Terragrunt can work around the limitations of Terraform in variety of ways.

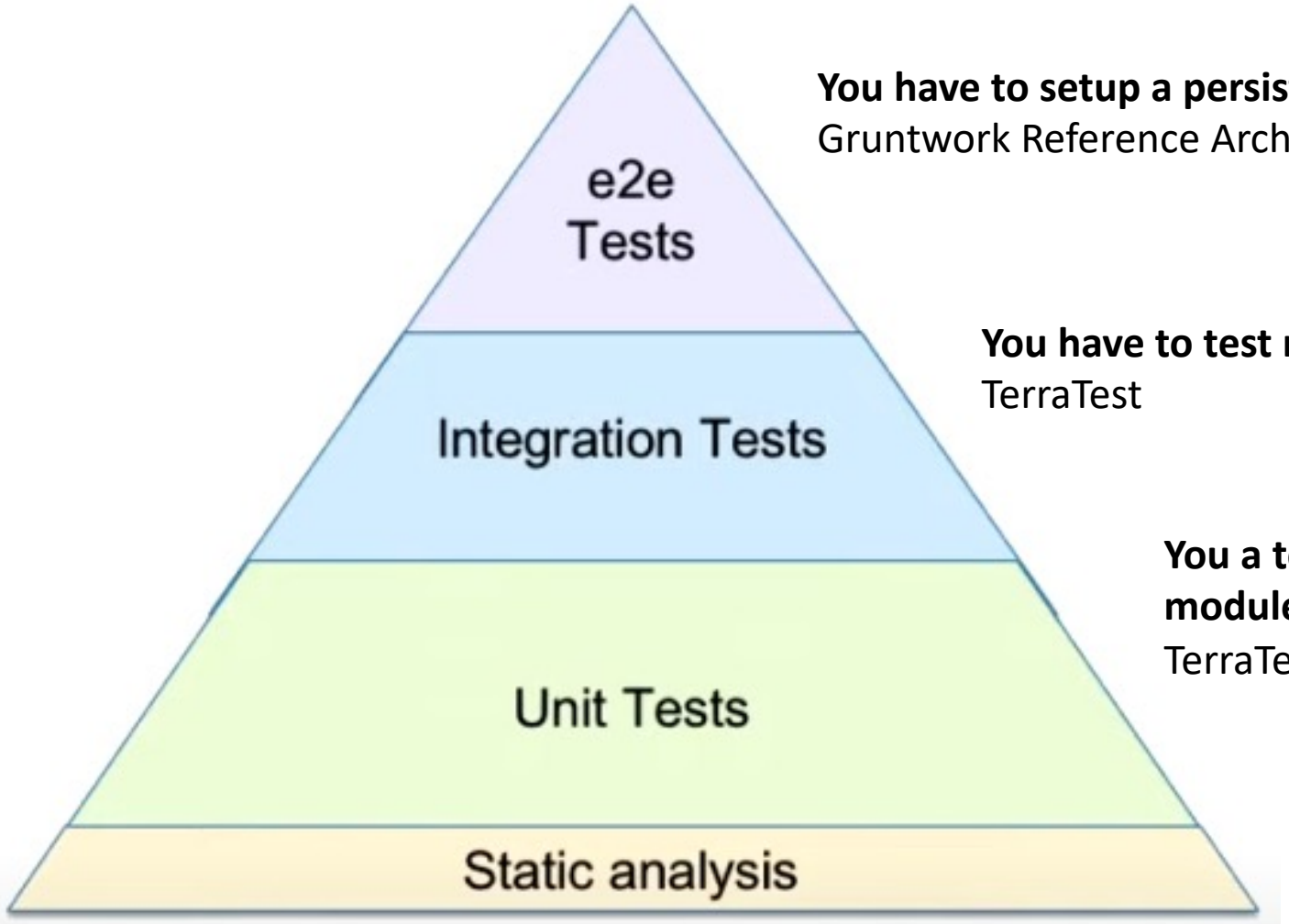
One example is **providing dynamic values to a provider** on definition which cannot be done with Terraform.

Terragrunt supports better granularity for modules by reducing lots of boilerplate.

This is important when you need to start writing UnitTests for your infrastructure

```
# Indicate where to source the terraform module from.
# The URL used here is a shorthand for
# "tfr://registry.terraform.io/terraform-aws-modules/vpc/aws?version=3.5.0".
# Note the extra `/` after the protocol is required for the shorthand
# notation.
terraform {
  source = "tfr:///terraform-aws-modules/vpc/aws?version=3.5.0"
}

# Indicate what region to deploy the resources into
generate "provider" {
  path = "provider.tf"
  if_exists = "overwrite_terragrunt"
  contents = <<EOF
provider "aws" {
  region = "us-east-1"
}
EOF
}

# Indicate the input values to use for the variables of the module.
inputs = {
  name = "my-vpc"
  cidr = "10.0.0.0/16"

  azs             = ["eu-west-1a", "eu-west-1b", "eu-west-1c"]
  private_subnets = ["10.0.1.0/24", "10.0.2.0/24", "10.0.3.0/24"]
  public_subnets  = ["10.0.101.0/24", "10.0.102.0/24", "10.0.103.0/24"]

  enable_nat_gateway = true
  enable_vpn_gateway = false
}
```

Testing in Terraform



You have to setup a persistent test environment.
Gruntwork Reference Architecture

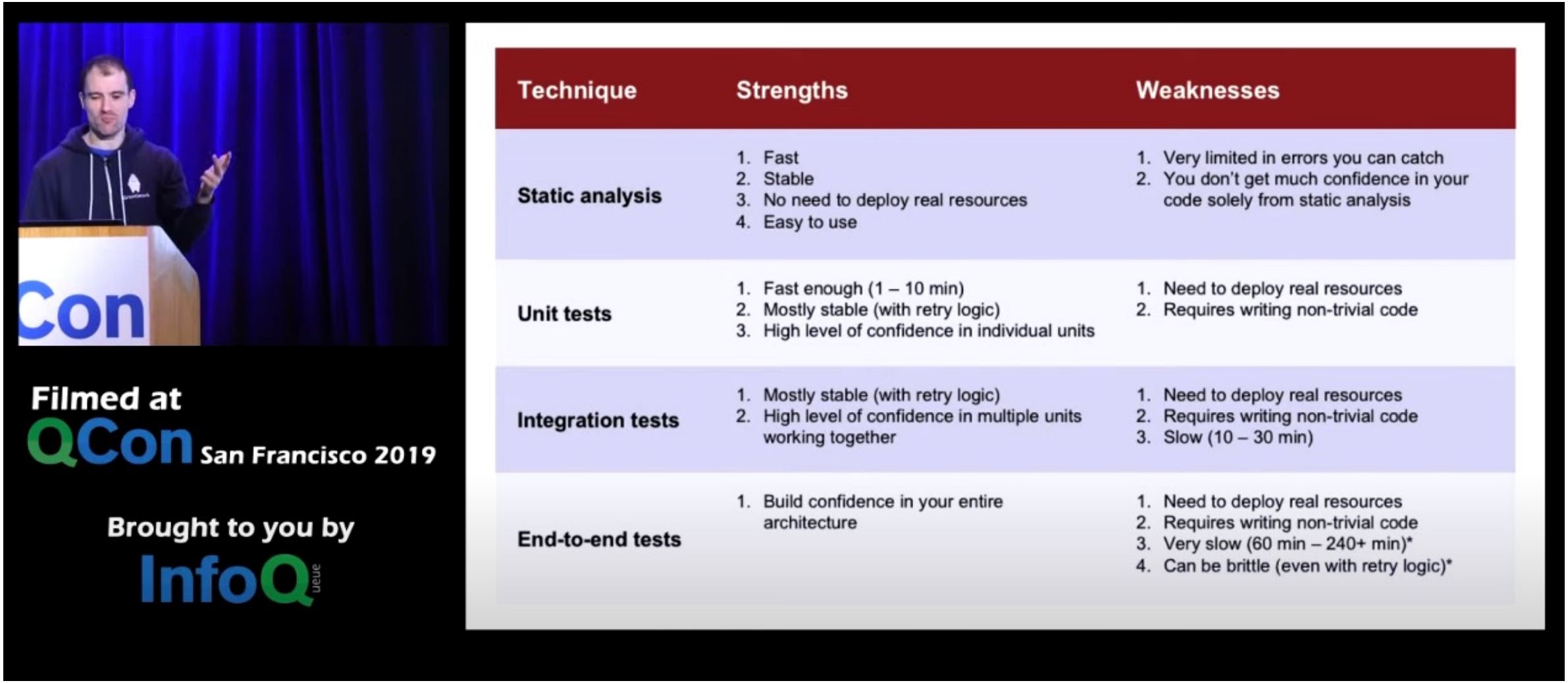
You have to test multiple IaC modules working together
TerraTest

You a testing a single module (you need to divide your modules into very small units of work)
TerraTest, Kitchen-terraform, Inspec

Test your code without deploying
Tflint, terraform validate, terraform plan, terraform-compliance, Sentinel

Testing in Terraform

Jim from GruntWork has a complete talk on Automated Testing for IaC.



Technique	Strengths	Weaknesses
Static analysis	1. Fast 2. Stable 3. No need to deploy real resources 4. Easy to use	1. Very limited in errors you can catch 2. You don't get much confidence in your code solely from static analysis
Unit tests	1. Fast enough (1 – 10 min) 2. Mostly stable (with retry logic) 3. High level of confidence in individual units	1. Need to deploy real resources 2. Requires writing non-trivial code
Integration tests	1. Mostly stable (with retry logic) 2. High level of confidence in multiple units working together	1. Need to deploy real resources 2. Requires writing non-trivial code 3. Slow (10 – 30 min)
End-to-end tests	1. Build confidence in your entire architecture	1. Need to deploy real resources 2. Requires writing non-trivial code 3. Very slow (60 min – 240+ min)* 4. Can be brittle (even with retry logic)*

Terra Test

TerraTest allows you to **perform Unit Test and Integration Tests** on your Infrastructure.

It tests your infrastructure by:

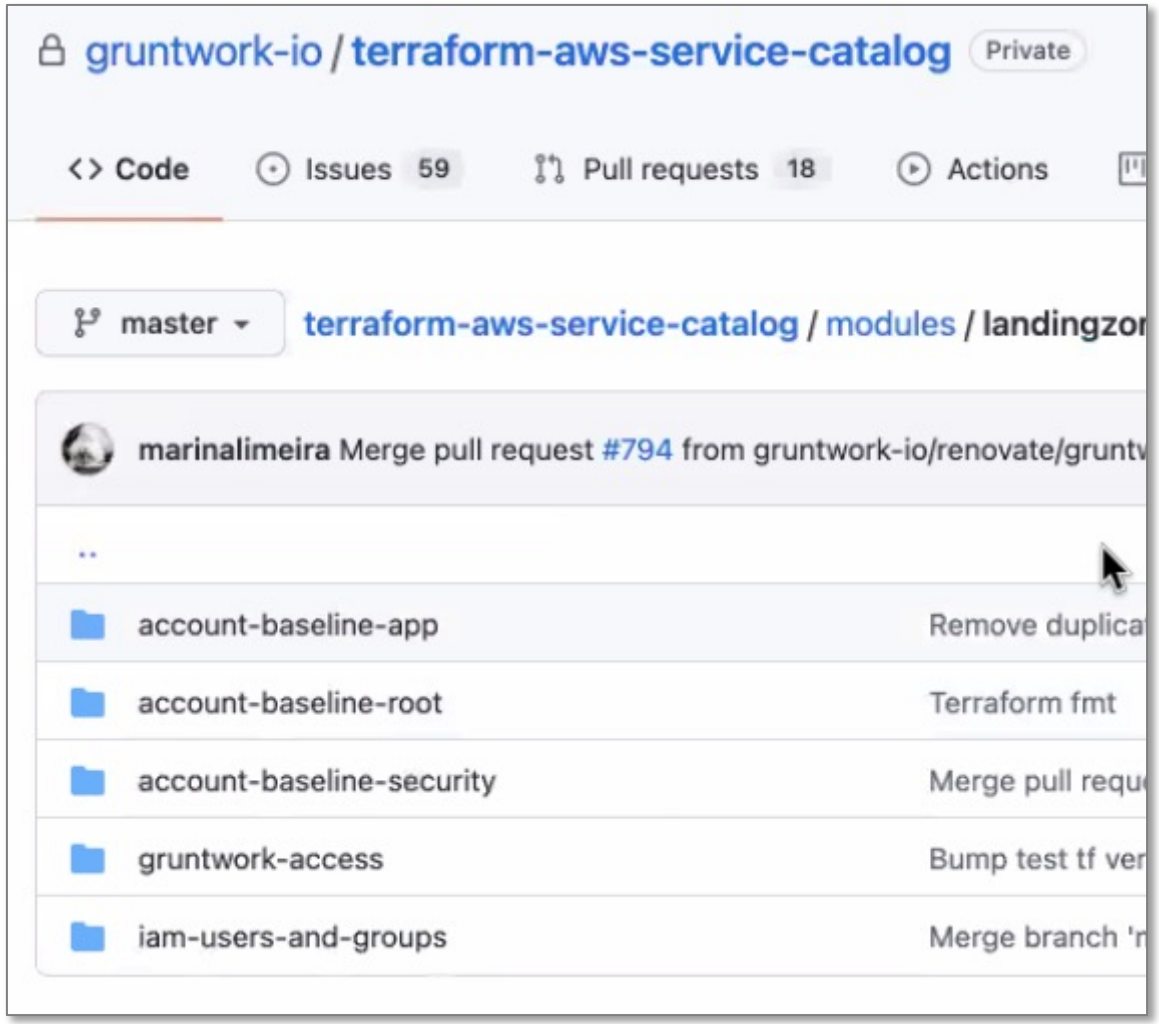
- temporarily deploying it
- validating the results
- then tearing down the test environment.

Tests in TerraTest are written in Golang.
You don't need to know much about Go to write tests.

```go
// Validate the "Hello, World" app is working
func validateHelloWorldApp(t *testing.T, terraformOptions *terraform.Options) {
    // Run `terraform output` to get the values of output variables
    url := terraform.Output(t, terraformOptions, "url")

    // Verify the app returns a 200 OK with the text "Hello, World!"
    expectedStatus := 200
    expectedBody := "Hello, World!"
    maxRetries := 10
    timeBetweenRetries := 3 * time.Second
    http_helper.HttpGetWithRetry(t, url, nil, expectedStatus, expectedBody, maxRetries, timeBetweenRetries)
}
```

Terragrunt

Terragrunt


gruntwork-io / terraform-aws-service-catalog
Private
Code
Issues 59
Pull requests 18
Actions
master
terraform-aws-service-catalog / modules / landingzon
marinalimeira Merge pull request #794 from gruntwork-io/renovate/gruntv
..
account-baseline-app
Remove duplica
account-baseline-root
Terraform fmt
account-baseline-security
Merge pull requ
gruntwork-access
Bump test tf ver
iam-users-and-groups
Merge branch 'r

Terragrunt - Features

Keep your Terraform Code DRY
Instead of repeating code, or having to create and publish your own modules, reference a tf file in a github repo at a specific location and instantiate by passing inputs

Keep your remote state configuration DRY
Adds support for expressions, variables, or function for remote backends e.g. S3

Keep your CLI Flags DRY - Pass along repeated CLI Flags

Execute Terraform commands on multiple modules at once
Instead of having to execute manually apply command in each subfolder, perform all at once.

Work with multiple AWS accounts
Assume roles for a security account to access resources across multiple accounts

Before and After Hooks - define custom actions that will be called either before or after execution of the terraform command

Auto-Init - automatically run Terraform Init when it would be required before a plan or apply.

Auto-Retry - automatically rerun a terraform command, in cases where rerunning would solve the problem e.g. networking problem

Terraform vs Terragrunt

Infrastructure as Code Library

The Infrastructure as Code Library contains serval open-source repository hosted on Github.

These libraries are battle-tested and opinionated but are well maintained by Guntwork for production-grade use cases, aligned to industry best practices.

The IaC Library covers:

- AWS, GCP, and Azure
- written in Terraform, Go, Bash, and Python

There is a mix of libraries for:

- paid (subscriber-only)
- free (open-source)

What's in the Library?

The Infrastructure as Code Library consists of 40+ GitHub repos, some open source, some private, each of which contains reusable, battle-tested infrastructure code for AWS, GCP, and Azure, written in Terraform, Go, Bash, and Python. Check out How to use the Gruntwork Infrastructure as Code Library to see how it all works.

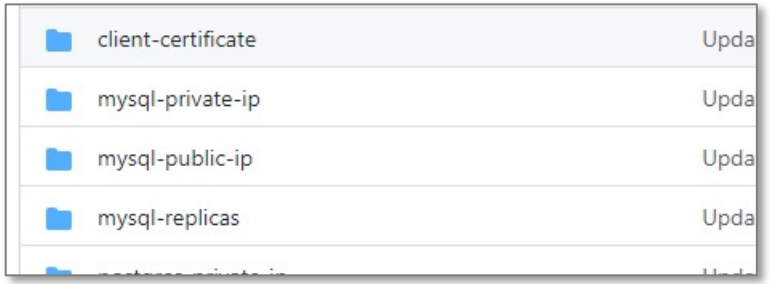
Search: *E.g., Try searching for Kubernetes, Vault, Jenkins, Kafka, Lambda, AWS, GCP, Azure, etc...*

Name	Description	Tags
AWS VPC	Create a best-practices Virtual Private Cloud (VPC) on AWS. Includes multiple subnet tiers, netwo...	aws, subscriber-only
Monitoring and Alerting	Configure monitoring, log aggregation, and alerting using CloudWatch, SNS, and S3. Includes Slack...	aws, subscriber-only
EC2 Container Service (ECS)	Deploy a best-practices ECS Cluster and run Docker containers on it as ECS Services. Includes zer...	aws, subscriber-only
EC2 Kubernetes Service (EKS)	Deploy a best-practices EKS cluster and run Docker containers on it as Kubernetes services. Suppo...	aws, subscriber-only
Kubernetes Services	Package services into a best-practices deployment for Kubernetes. Supports zero-downtime, rolling...	aws, gcp, azure, open source
Auto Scaling Group	Run stateless and stateful services on top of an Auto Scaling Group. Supports zero-downtime, roll...	aws, subscriber-only

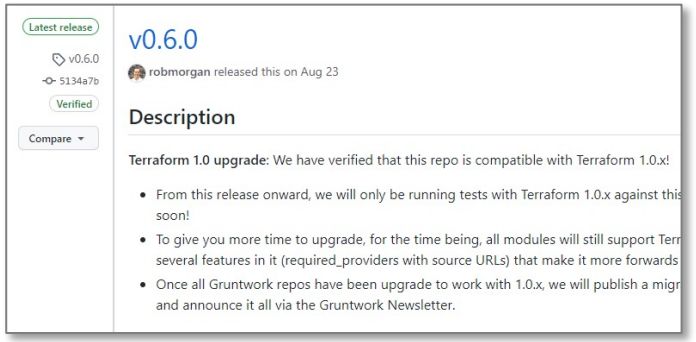
IaC Library Core Concepts

All publishes IaC Libraries have the following:

Examples
All IaC Libraries contain multiple examples for common production-grade use-cases



Versioning
All IaC Libraries following strict versioning guidelines will well written descriptions.



Automated Tests

Gruntwork Reference Architecture

An **opinionated, battle-tested, best-practices way** to assemble infrastructure code from the **Infrastructure as Code Library**

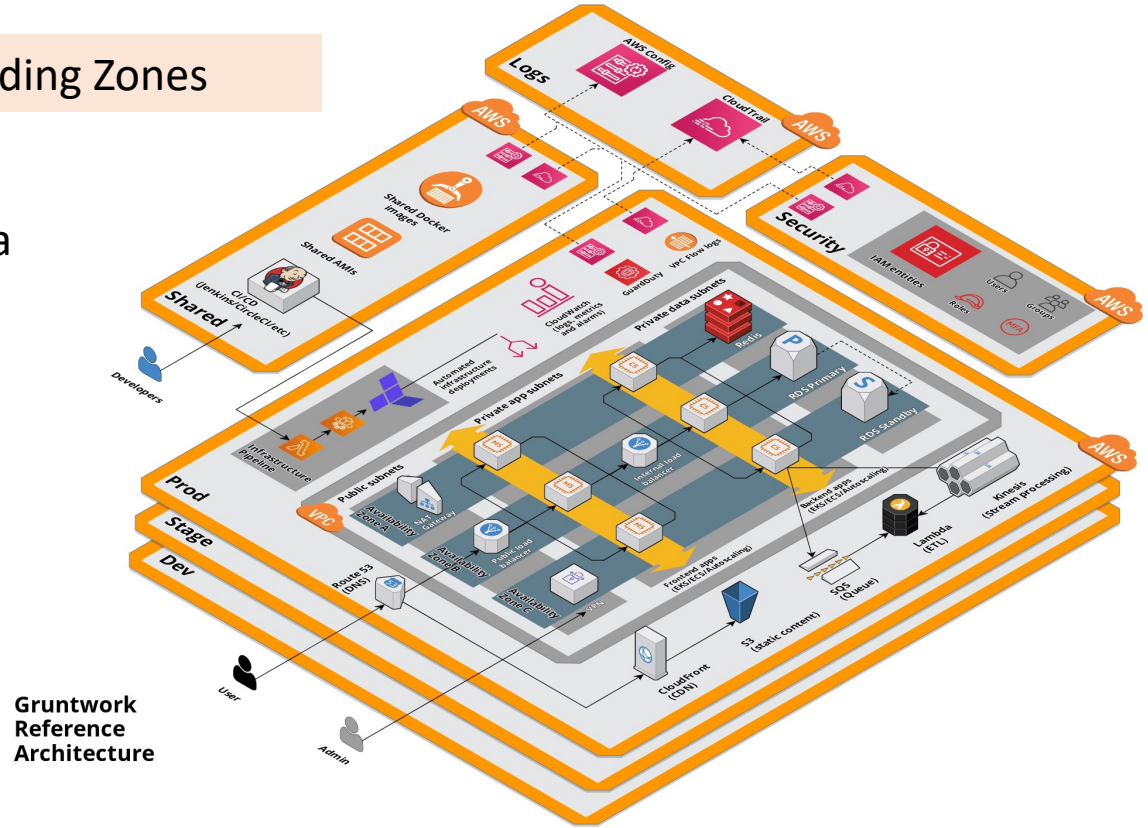
Reference Architecture *is the Terraform Equivalent* to AWS Landing Zones

What is a Landing Zone?
A Landing Zone is foundational infrastructure that establishes a security and operation **production-grade** baseline for your cloud workloads.

Guntwork offers a compliant version of Reference Architecture based on the **CIS** AWS Foundations Benchmark

Center of Internet Security

The Reference Architect is only available to Gruntwork Subscribers *(paid customers of Gruntwork)*



Gruntwork Reference Architecture

TfLint

terraform-compliance