TERRAFORM
COMPREHENSIVE TRAINING

Taught by
Gruntwork

http://gruntwork.io

Gruntwork

http://gruntwork.io

We've pre-written Terraform packages for the most common AWS components.

We test, update, and support these packages.

When a software team purchases a package, they get 100% of the source code.

Gruntwork

http://gruntwork.io

Sample Packages

- Network Topology (VPC)
- Monitoring and Alerting
- Docker Cluster
- Continuous Delivery

Code samples:

github.com/gruntwork-io/infrastructure-as-code-training

Outline

1. Intro
2. State
3. Modules
4. Best practices
5. Gotchas
6. Recap

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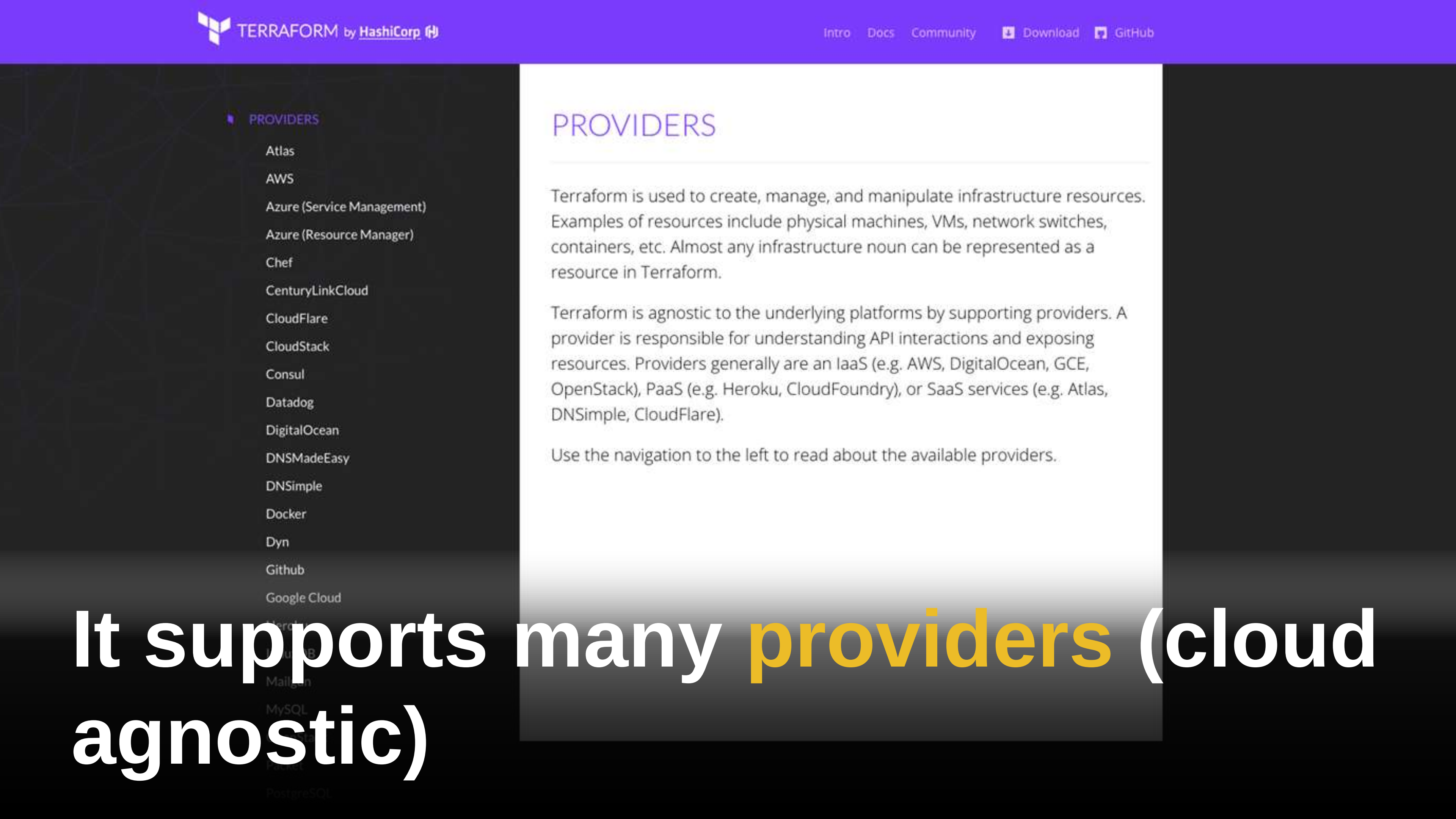
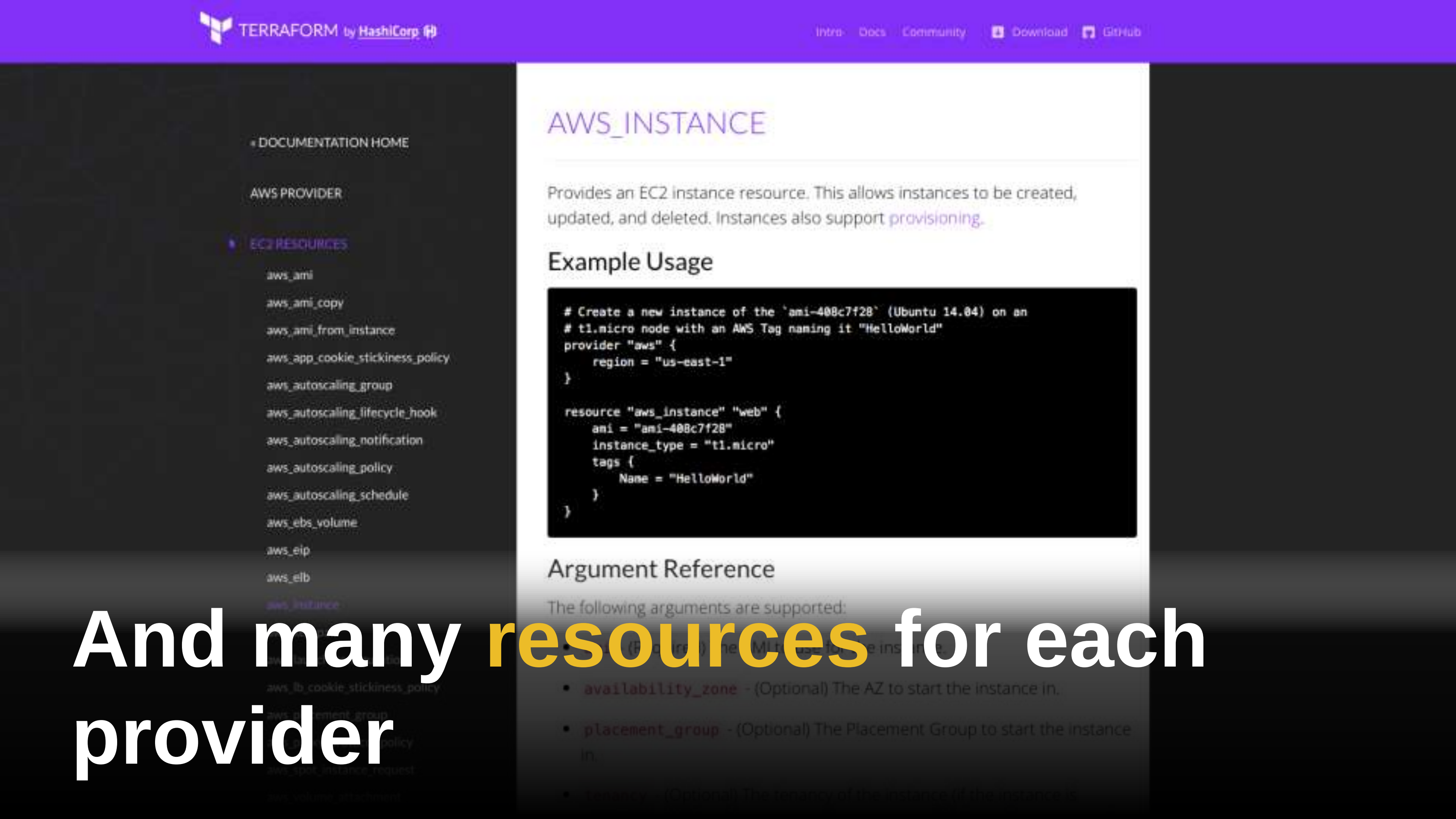
TERRAFORM

Terraform is a tool for provisioning infrastructure



It supports many **providers** (cloud agnostic)



And many **resources** for each provider

You define resources as **code** in **Terraform templates**

```
provider "aws" {
  region = "us-east-1"
}

resource "aws_instance" "example" {
    ami = "ami-408c7f28"
    instance_type = "t2.micro"
    tags { Name = "terraform-example" }
}
```

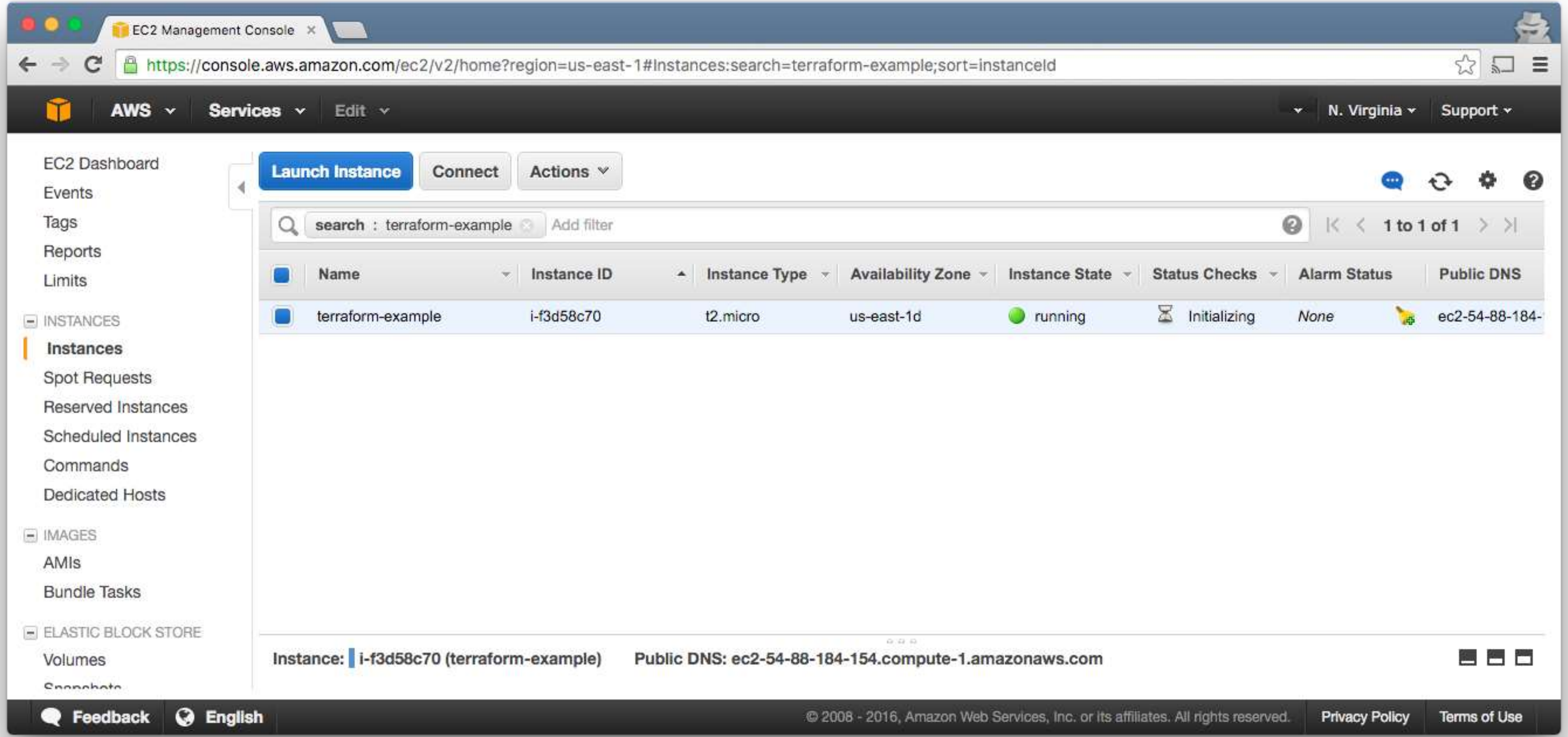
This template creates a single EC2 instance in AWS

```
> terraform plan
+ aws_instance.example
    ami:                    "" => "ami-408c7f28"
    instance_type:          "" => "t2.micro"
    key_name:               "" => "<computed>"
    private_ip:             "" => "<computed>"
    public_ip:              "" => "<computed>"

Plan: 1 to add, 0 to change, 0 to destroy.
```

Use the plan command to see what you’re about to deploy

```
> terraform apply
aws_instance.example: Creating...
    ami:                          "" => "ami-408c7f28"
    instance_type:                "" => "t2.micro"
    key_name:                     "" => "<computed>"
    private_ip:                   "" => "<computed>"
    public_ip:                    "" => "<computed>”
aws_instance.example: Creation complete

Apply complete! Resources: 1 added, 0 changed, 0 destroyed.
```

Use the `apply` command to apply the changes



Now the EC2 instance is running!

You can parameterize your templates using **variables**

```
variable "name" {
    description = "The name of the EC2 instance"
}
```

Define a variable. `description`, `default`, **and** `type` **are optional.**

```
variable "name" {
    description = "The name of the EC2 instance"
}

resource "aws_instance" "example" {
    ami = "ami-408c7f28"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}
```

Note the use of `${}` syntax to reference `var.name` in tags

```
> terraform plan
var.name
  Enter a value: foo

~ aws_instance.example
    tags.Name: "terraform-example" => "foo"
```

Use `plan` to verify your changes. It prompts you for the variable.

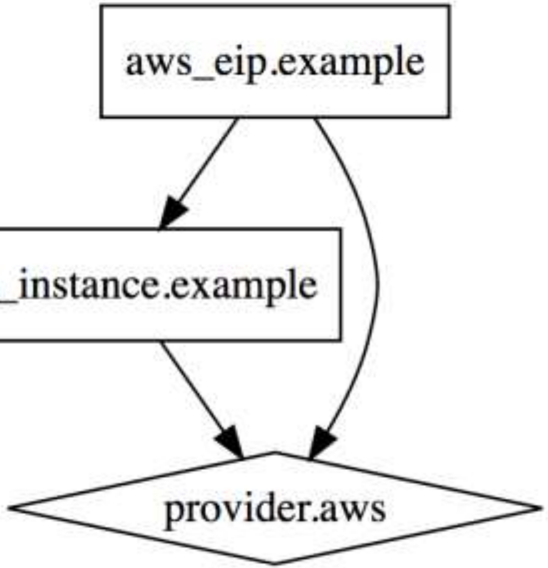
```
> terraform apply -var name=foo
aws_instance.example: Refreshing state...
aws_instance.example: Modifying...
tags.Name: "terraform-example" => "foo"
aws_instance.example: Modifications complete

Apply complete! Resources: 0 added, 1 changed, 0 destroyed.
```

You can also pass variables using the `-var` parameter

You can create **dependencies** between resources

```
resource "aws_eip" "example" {
    instance = "${aws_instance.example.id}”
}

resource "aws_instance" "example" {
    ami = "ami-408c7f28"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}
```

Notice the use of `${}` to depend on the `id` of the `aws_instance`



Terraform automatically builds a dependency graph

You can clean up all resources you created with Terraform

```
> terraform destroy
aws_instance.example: Refreshing state... (ID: i-f3d58c70)
aws_elb.example: Refreshing state... (ID: example)
aws_elb.example: Destroying...
aws_elb.example: Destruction complete
aws_instance.example: Destroying...
aws_instance.example: Destruction complete

Apply complete! Resources: 0 added, 0 changed, 2 destroyed.
```

Just use the `destroy` command

```
> terraform destroy
aws_instance.example: Refreshing state... (ID: i-f3d58c70)
aws_elb.example: Refreshing state... (ID: example)
aws_elb.example: Destroying...
aws_elb.example: Destruction complete
aws_instance.example: Destroying...
aws_instance.example: Destruction complete

Apply complete! Resources: 0 added, 0 changed, 2 destroyed.
```

But how did Terraform know what to destroy?

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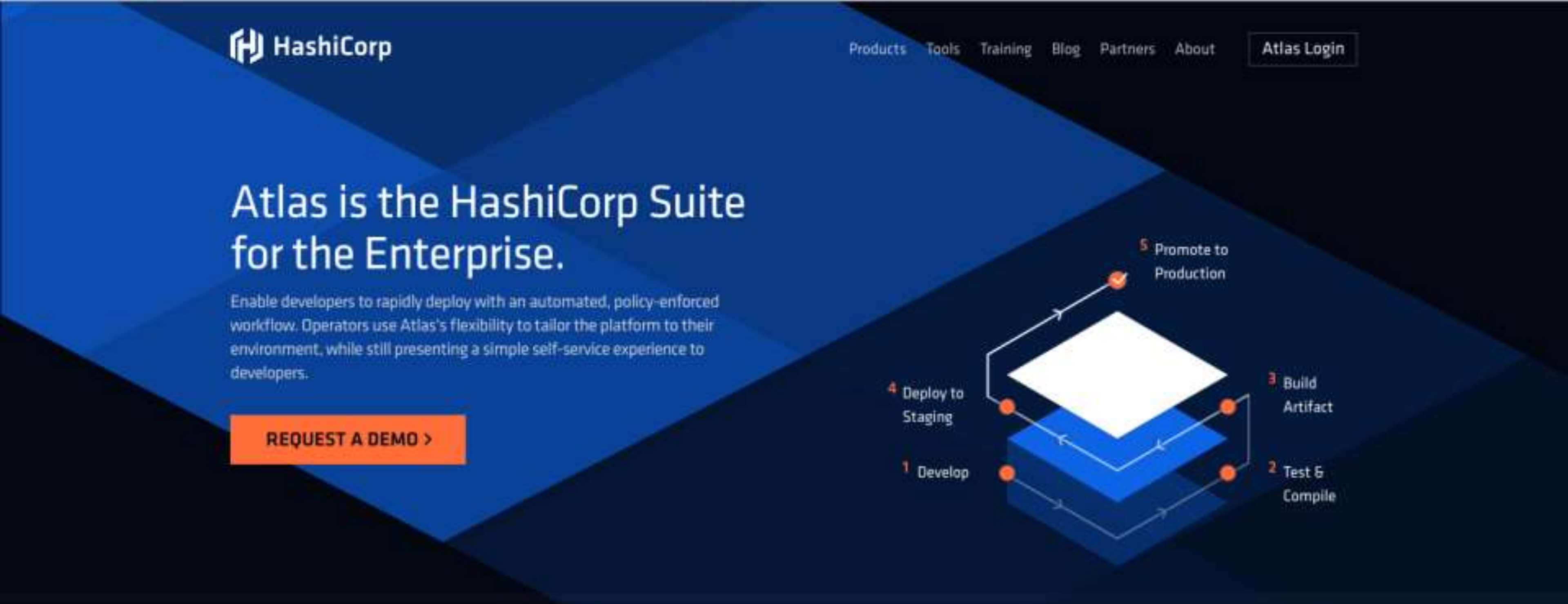
Terraform records state of everything it has done

```
> ls -al
-rw-r--r--  6024 Apr  5 17:58 terraform.tfstate
-rw-r--r--  6024 Apr  5 17:58 terraform.tfstate.backup
```

By default, state is stored locally in `.tfstate` files

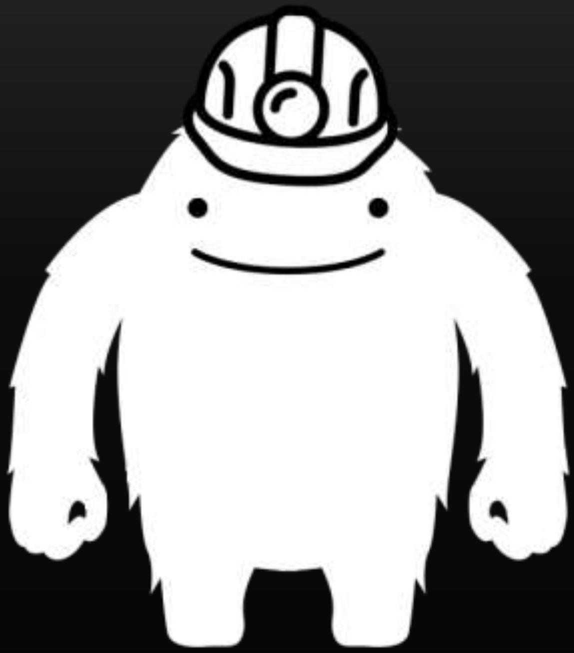
```
> terraform remote config \
  -backend=s3 \
  -backend-config=bucket=my-s3-bucket \
  -backend-config=key=terraform.tfstate
  -backend-config=encrypt=true \
  -backend-config=region=us-east-1
```

You can enable remote state storage in S3, Atlas, Consul, etc.



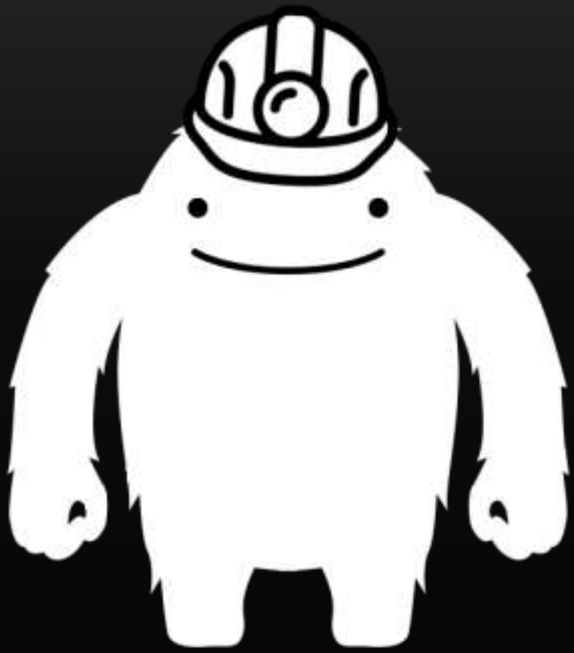
Only Atlas provides locking, but it can be expensive

One alternative: manual coordination (+ CI job)



Better alternative: terragrunt

github.com/gruntwork-io/terragrunt



Terragrunt is a thin, open source wrapper for Terraform

It provides locking using **DynamoDB**

```
dynamoDbLock = {
  stateFileId = "mgmt/bastion-host"
}

remoteState = {
  backend = "s3"
  backendConfigs = {
    bucket = "acme-co-terraform-state"
    key = "mgmt/bastion-host/terraform.tfstate"
  }
}
```

Terragrunt looks for a `.terragrunt` file for its configuration.

```
> terragrunt plan
> terragrunt apply
> terragrunt destroy
```

Use all the normal Terraform commands with Terragrunt

```
> terragrunt apply
[terragrunt] Acquiring lock for bastion-host in DynamoDB
[terragrunt] Running command: terraform apply

aws_instance.example: Creating...
  ami:                          "" => "ami-0d729a60"
  instance_type:                "" => "t2.micro”
[...]
Apply complete! Resources: 1 added, 0 changed, 0 destroyed.

[terragrunt] Releasing lock for bastion-host in DynamoDB
```

Terragrunt automatically acquires and releases locks on `apply/destroy`

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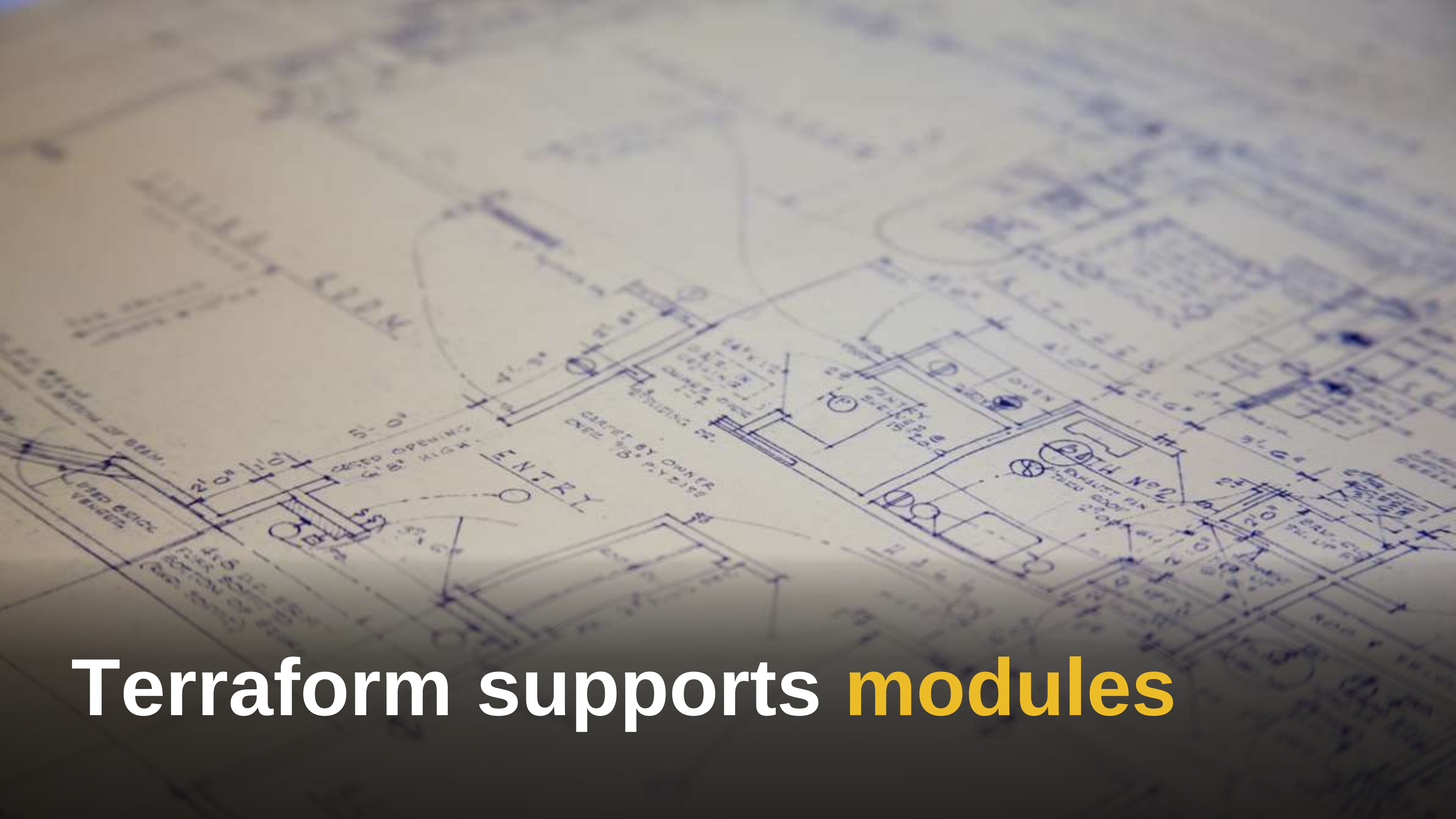
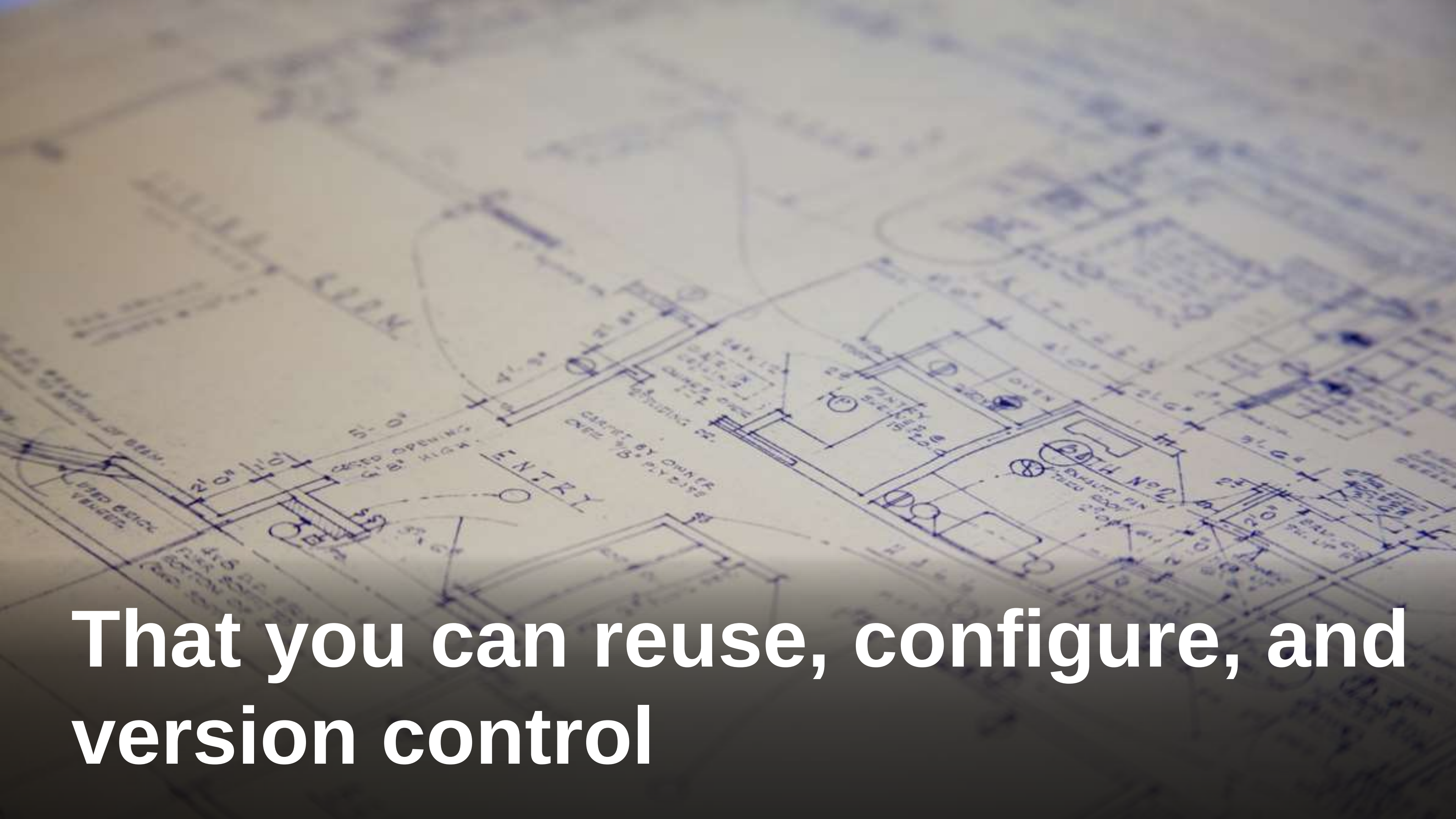
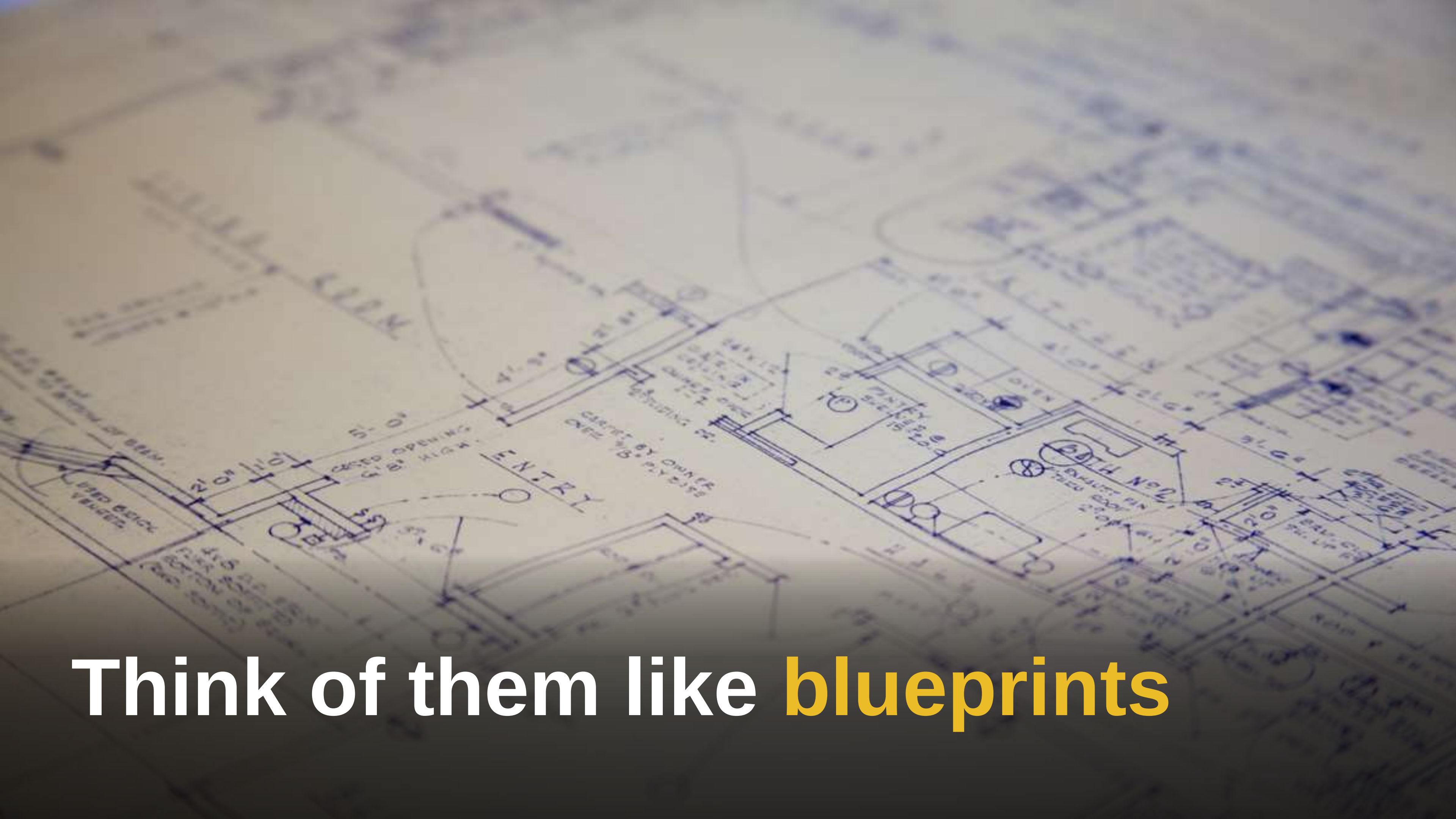
Terraform supports modules





That you can reuse, configure, and version control



Think of them like **blueprints**

A module is just a folder with Terraform templates

Most Gruntwork Infrastructure Packages are Terraform modules

Our conventions:

1. vars.tf
2. main.tf
3. outputs.tf

```
variable "name" {
    description = "The name of the EC2 instance"
}

variable "ami" {
    description = "The AMI to run on the EC2 instance"
}

variable "port" {
    description = "The port to listen on for HTTP requests"
}
```

Specify module inputs in `vars.tf`

```
resource "aws_instance" "example" {
    ami = "${var.ami}"
    instance_type = "t2.micro"
    user_data = "${template_file.user_data.rendered}"
    tags { Name = "${var.name}" }
}
```

Create **resources** in `main.tf`

```
output "url" {
    value = "http://${aws_instance.example.ip}:${var.port}"
}
```

Specify outputs in `outputs.tf`

See example modules:

gruntwork.io/#what-we-do

Using a module:

```
module "example_rails_app" {
    source = "./rails-module"
}
```

The `source` parameter specifies what module to use

```
module "example_rails_app" {
    source = "git::git@github.com:foo/bar.git//module?ref=0.1"
}
```

It can even point to a versioned Git URL

```
module "example_rails_app" {
    source = "git::git@github.com:foo/bar.git//module?ref=0.1"

    name = "Example Rails App"
    ami = "ami-123asd1"
    port = 8080
}
```

Specify the module’s inputs like any other Terraform resource

```
module "example_rails_app_stg" {
    source = "./rails-module"
    name = "Example Rails App staging"
}

module "example_rails_app_prod" {
    source = "./rails-module"
    name = "Example Rails App production"
}
```

You can reuse the same module multiple times

```
> terraform get -update

Get: file:///home/ubuntu/modules/rails-module
Get: file:///home/ubuntu/modules/rails-module
Get: file:///home/ubuntu/modules/asg-module
Get: file:///home/ubuntu/modules/vpc-module
```

Run the `get` command before running `plan` or `apply`

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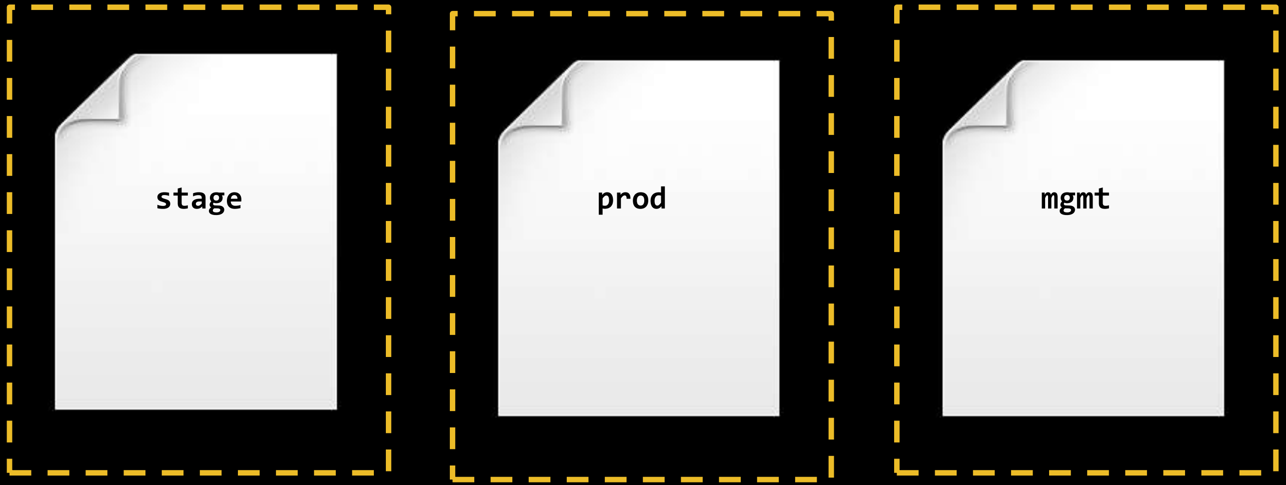
1. `Plan` **before** `apply`

2. Stage before prod

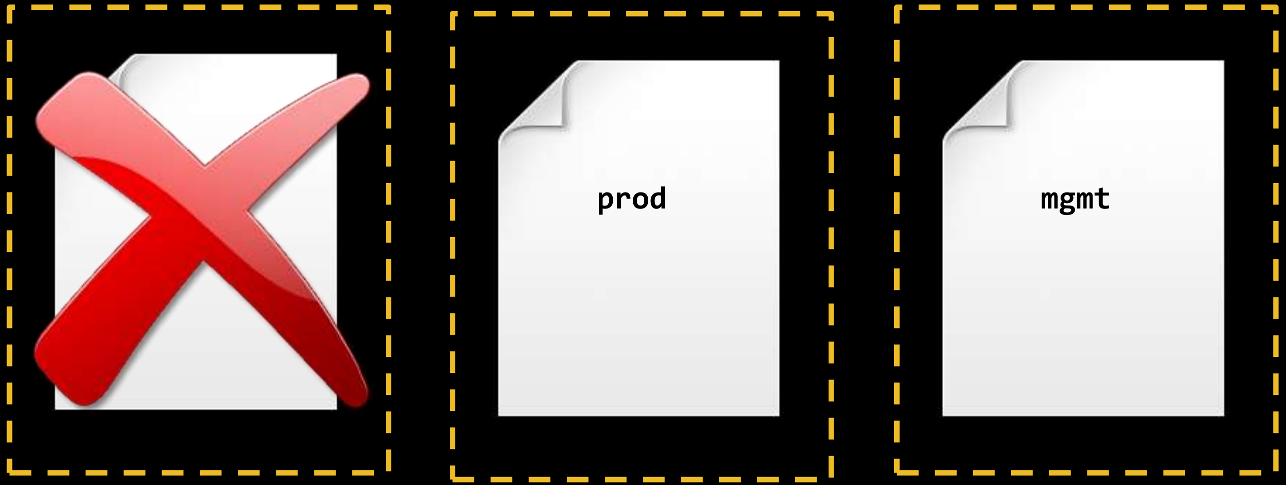
3. Isolated environments

It’s tempting to define everything in 1 template

But then a mistake anywhere could break everything



What you really want is **isolation** for each environment



That way, a problem in stage doesn't affect prod

Recommended folder structure (simplified):

```
global (Global resources such as IAM, SNS, S3)
  └ main.tf
  └ .terragrunt

stage (Non-production workloads, testing)
  └ main.tf
  └ .terragrunt

prod (Production workloads, user-facing apps)
  └ main.tf
  └ .terragrunt

mgmt (DevOps tooling such as Jenkins, Bastion Host)
  └ main.tf
  └ .terragrunt
```

```
global (Global resources such as IAM, SNS, S3)
  └ main.tf
  └ .terragrunt

stage (Non-production workloads, testing)
  └ main.tf
  └ .terragrunt

prod (Production workloads, user-facing apps)
  └ main.tf
  └ .terragrunt

mgmt (DevOps tooling such as Jenkins, Bastion Host)
  └ main.tf
  └ .terragrunt
```

Each folder gets its own `.tfstate`

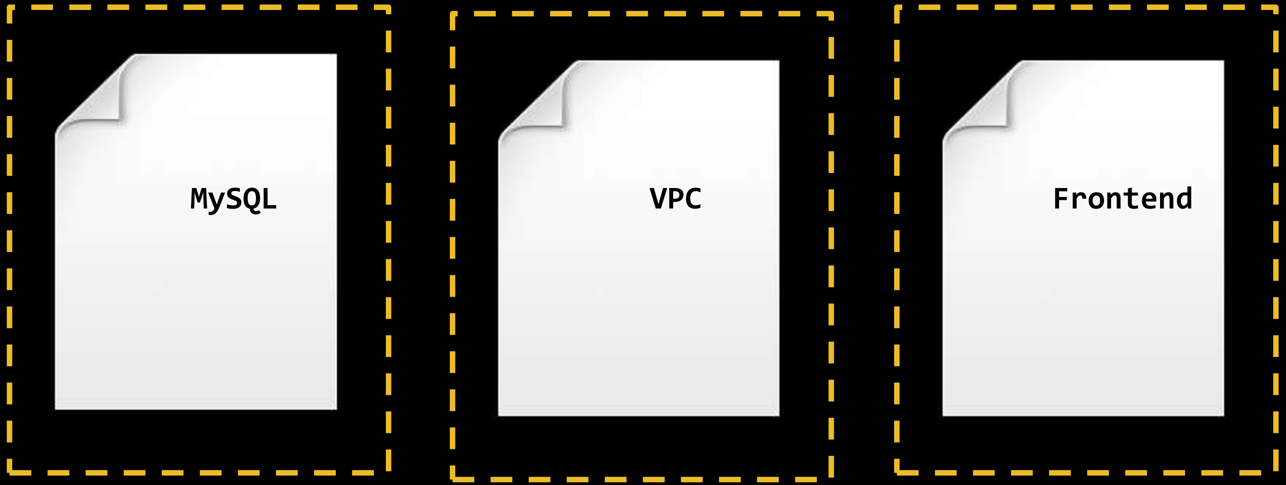
```
global (Global resources such as IAM, SNS, S3)
  └ main.tf
  └ .terragrunt

stage (Non-production workloads, testing)
  └ main.tf
  └ .terragrunt

prod (Production workloads, user-facing apps)
  └ main.tf
  └ .terragrunt

mgmt (DevOps tooling such as Jenkins, Bastion Host)
  └ main.tf
  └ .terragrunt
```

Use `terraform_remote_state` to share state between them

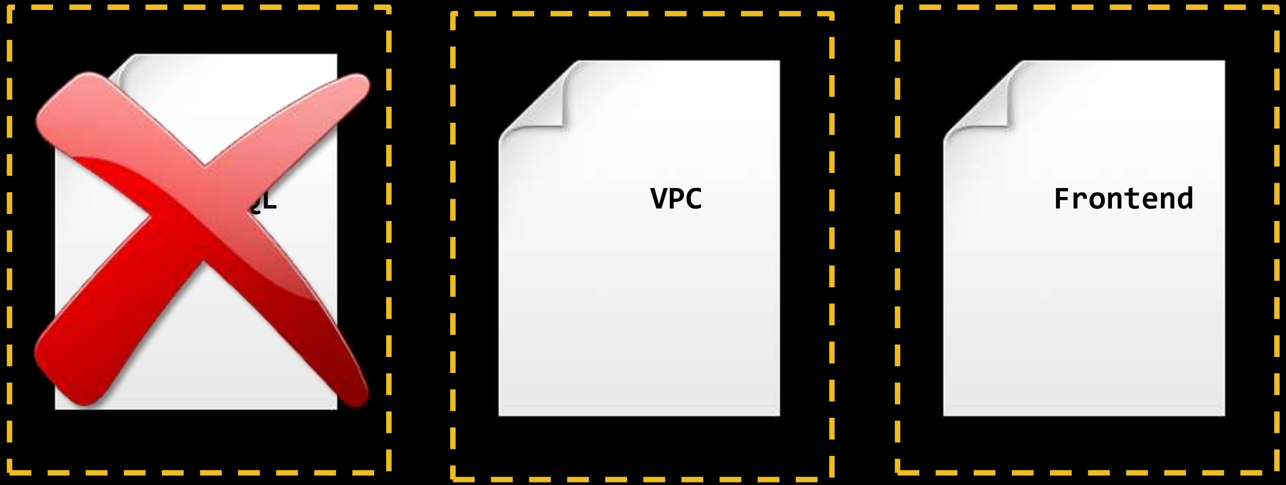
4. Isolated components

It’s tempting to define everything in 1 template

But then a mistake anywhere could break everything



What you really want is **isolation** for each component



That way, a problem in MySQL doesn’t affect the whole VPC

Recommended folder structure (full):

```
global (Global resources such as IAM, SNS, S3)
  └ iam
  └ sns

stage (Non-production workloads, testing)
  └ vpc
  └ mysql
  └ frontend

prod (Production workloads, user-facing apps)
  └ vpc
  └ mysql
  └ frontend

mgmt (DevOps tooling such as Jenkins, Bastion Host)
  └ vpc
  └ bastion
```

```
global (Global resources such as IAM, SNS, S3)
   └ iam
   └ sns

stage (Non-production workloads, testing)
   └ vpc
   └ mysql
   └ frontend

prod (Production workloads, user-facing apps)
   └ vpc
   └ mysql
   └ frontend

mgmt (DevOps tooling such as Jenkins, Bastion Host)
   └ vpc
   └ bastion
```

Each component in each environment gets its own .tfstate

```
global (Global resources such as IAM, SNS, S3)
  └ iam
  └ sns

stage (Non-production workloads, testing)
  └ vpc
  └ mysql
  └ frontend

prod (Production workloads, user-facing apps)
  └ vpc
  └ mysql
  └ frontend

mgmt (DevOps tooling such as Jenkins, Bastion Host)
  └ vpc
  └ bastion
```

Use terraform_remote_state to share state between them

5. Use modules

```
stage
  └ vpc
  └ mysql
  └ frontend
prod
  └ vpc
  └ mysql
  └ frontend
```

How do you avoid copy/pasting code between stage and prod?

```
stage
  └ vpc
  └ mysql
  └ frontend
prod
  └ vpc
  └ mysql
  └ frontend
```

```
modules
  └ vpc
  └ mysql
  └ frontend
```

Define **reusable modules**!

```
stage
  └ vpc
  └ mysql
  └ frontend
prod
  └ vpc
  └ mysql
  └ frontend
```

```
modules
  └ vpc
  └ mysql
  └ frontend
    └ main.tf
    └ outputs.tf
    └ vars.tf
```

Each module defines one reusable component

```
variable "name" {
    description = "The name of the EC2 instance"
}

variable "ami" {
    description = "The AMI to run on the EC2 instance"
}

variable "memory" {
    description = "The amount of memory to allocate"
}
```

Define **inputs** in `vars.tf` to configure the module

```
module "frontend" {
    source = "./modules/frontend"

    name = "frontend-stage"
    ami = "ami-123asd1"
    memory = 512
}
```

Use the module in stage

(stage/frontend/main.tf)

```
module "frontend" {
    source = "./modules/frontend"

    name = "frontend-prod"
    ami = "ami-123abcd"
    memory = 2048
}
```

And in prod

(prod/frontend/main.tf)

6. Use versioned modules

```
stage                                modules
  └ vpc                                └ vpc
  └ mysql                              └ mysql
  └ frontend                           └ frontend
prod
  └ vpc
  └ mysql
  └ frontend
```

If stage and prod point to the same folder, you lose isolation

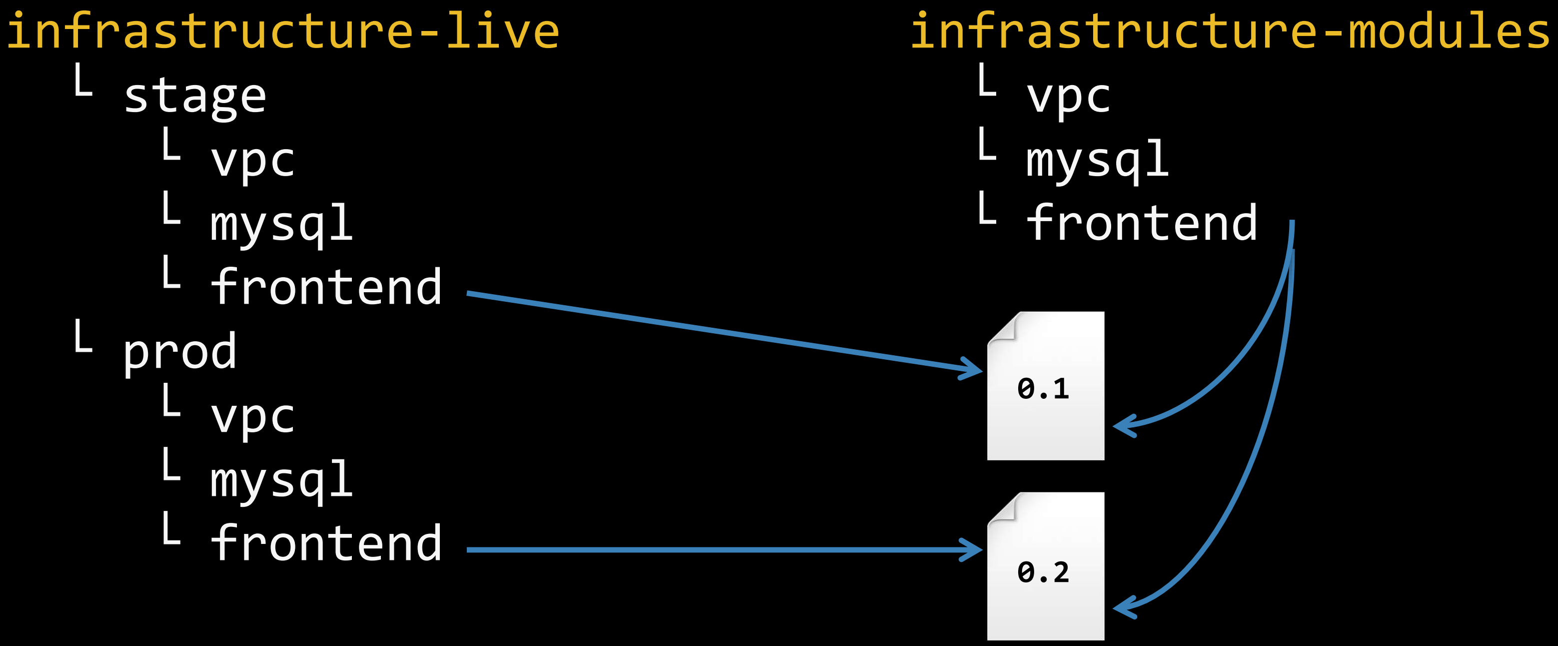
```
stage                              modules
  └ vpc                              └ vpc
  └ mysql                            └ mysql
  └ frontend                         └ frontend
prod
  └ vpc
  └ mysql
  └ frontend
```

Any change in `modules/frontend` affects both stage and prod

```
infrastructure-live
  └ stage
     └ vpc
     └ mysql
     └ frontend
  └ prod
     └ vpc
     └ mysql
     └ frontend
```

```
infrastructure-modules
  └ vpc
  └ mysql
  └ frontend
```

Solution: define modules in a separate repository

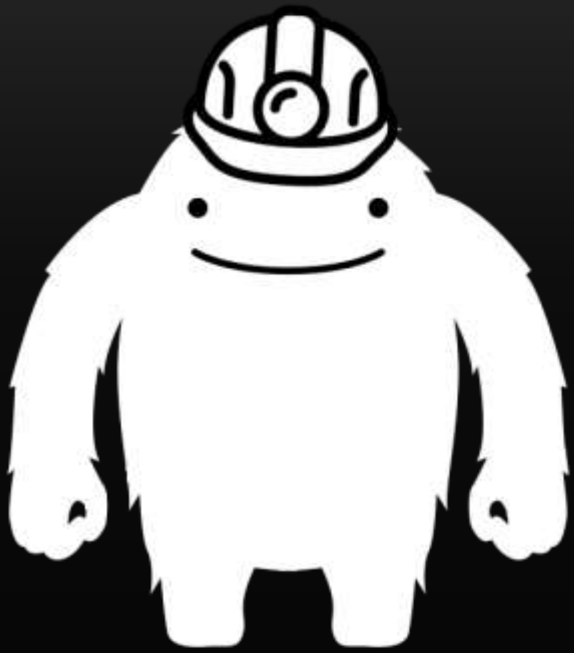


Now stage and prod can use different versioned URLs

```
module "frontend" {
    source =
"git::git@github.com:foo/infrastructure-modules.git//frontend?ref=0.2"

    name = "frontend-prod"
    ami = "ami-123abcd"
    memory = 2048
}
```

Example Terraform code (prod/frontend/main.tf)

7. State file storage



Use terragrunt

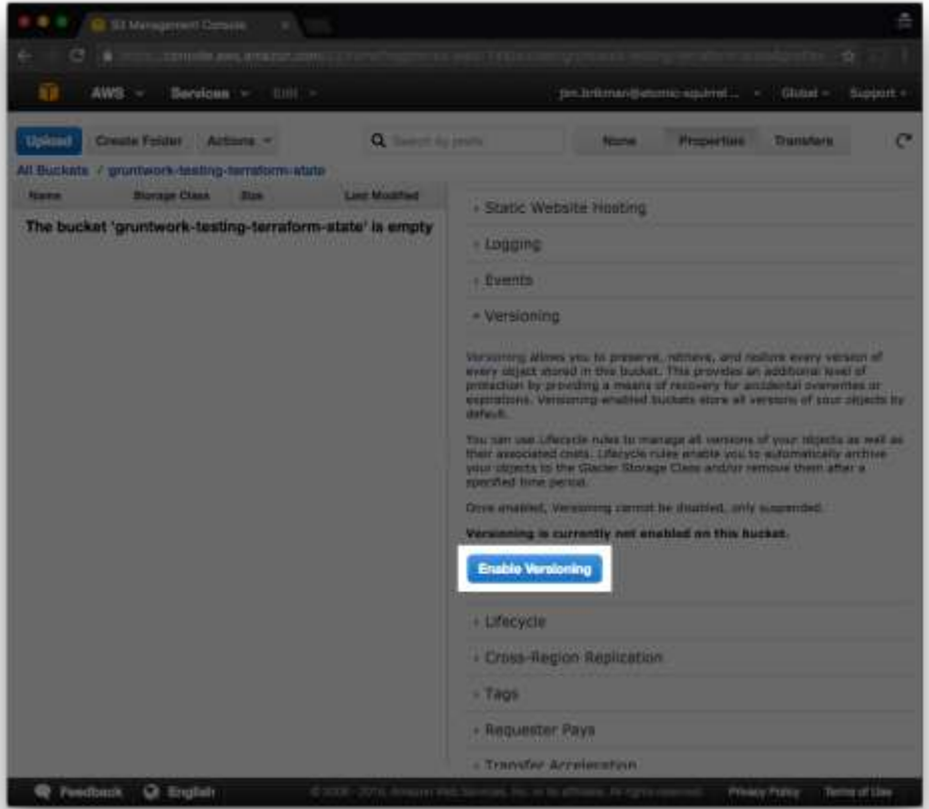
github.com/gruntwork-io/terragrunt

```
dynamoDbLock = {
  stateFileId = "mgmt/bastion-host"
}
```

Use a custom lock (`stateFileId`) for each set of templates

```
remoteState = {
  backend = "s3"
  backendConfigs = {
    bucket = "acme-co-terraform-state"
    key = "mgmt/bastion-host/terraform.tfstate"
    encrypt = "true"
  }
}
```

Use an S3 bucket with encryption for remote state storage



Enable versioning on the S3 bucket!

7. Loops

Terraform is declarative, so very little "logic" is possible…

But you can "loop" to create multiple resources using count

```
resource "aws_instance" "example" {
    count = 1
    ami = "${var.ami}"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}
```

Create one EC2 Instance

```
resource "aws_instance" "example" {
    count = 3
    ami = "${var.ami}"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}
```

Create three EC2 Instances

Use `count.index` to modify each “iteration”

```
resource "aws_instance" "example" {
    count = 3
    ami = "${var.ami}"
    instance_type = "t2.micro"
    tags { Name = "${var.name}-${count.index}" }
}
```

Create three EC2 Instances, each with a different name

Do even more with interpolation functions:

terraform.io/docs/configuration/interpolation.html

```
resource "aws_instance" "example" {
    count = 3
    ami = "${element(var.amis, count.index)}"
    instance_type = "t2.micro"
    tags { Name = "${var.name}-${count.index}" }
}

variable "amis" {
  type = "list"
  default = ["ami-abc123", "ami-abc456", "ami-abc789"]
}
```

Create three EC2 Instances, each with a different AMI

```
output "all_instance_ids" {
    value = ["${aws_instance.example.*.id}"]
}

output "first_instance_id" {
    value = "${aws_instance.example.0.id}"
}
```

Note: resources with count are actually lists of resources!

8. If-statements

Terraform is declarative, so very little “logic” is possible…

But you can do a limited form of if-statement using count

```
resource "aws_instance" "example" {
    count = "${var.should_create_instance}"
    ami = "ami-abcd1234"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}

variable "should_create_instance" {
  default = true
}
```

Note the use of a `boolean` in the count parameter

In HCL:

- `true  = 1`
- `false = 0`

```
resource "aws_instance" "example" {
    count = "${var.should_create_instance}"
    ami = "ami-abcd1234"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}

variable "should_create_instance" {
  default = true
}
```

So this creates 1 EC2 Instance if `should_create_instance` is true

```
resource "aws_instance" "example" {
    count = "${var.should_create_instance}"
    ami = "ami-abcd1234"
    instance_type = "t2.micro"
    tags { Name = "${var.name}" }
}

variable "should_create_instance" {
  default = true
}
```

Or 0 EC2 Instances if `should_create_instance` is false

It’s equivalent to:

```
if (should_create_instance)
   create_instance()
```

There are many permutations of this trick (e.g. using length)

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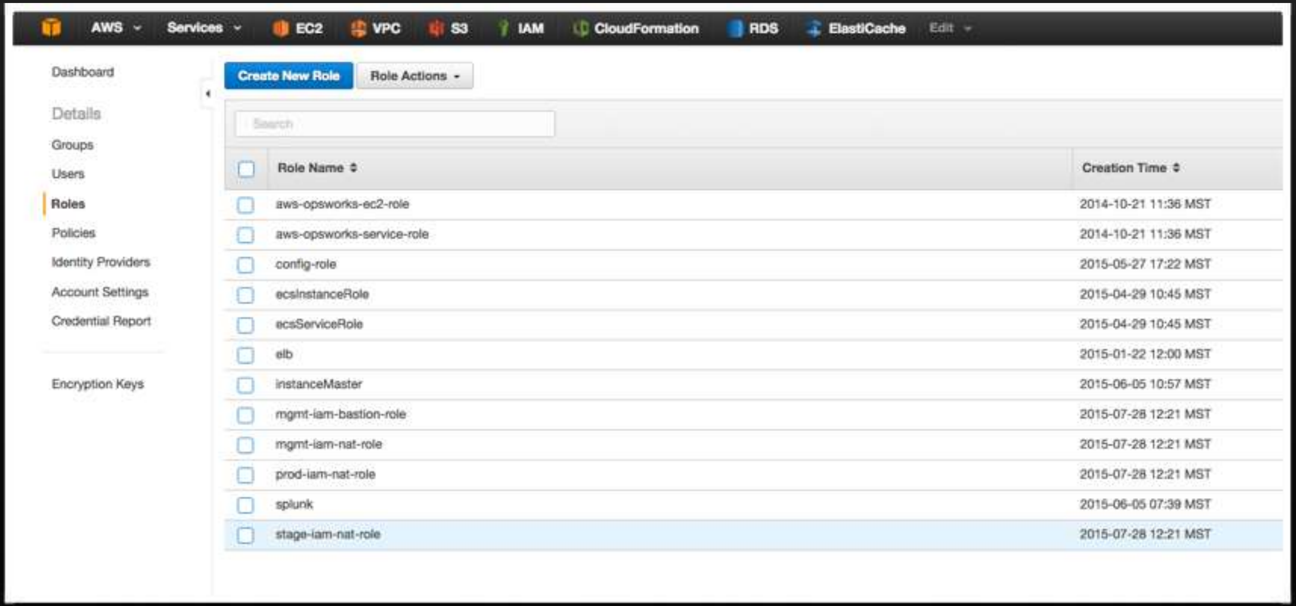
1. Valid plans can fail

```
> terraform plan
+ aws_iam_instance_profile.instance_profile
    arn:                  "<computed>"
    create_date:          "<computed>"
    name:                 "stage-iam-nat-role"
    path:                 "/"
    roles.2760019627: "stage-iam-nat-role"
    unique_id:            "<computed>”

Plan: 1 to add, 0 to change, 0 to destroy.
```

Valid plan to create IAM instance profiles



But the instance profile already exists in IAM!

```
> terraform apply

Error applying plan:

* Error creating IAM role stage-iam-nat-role:
EntityAlreadyExists: Role with name stage-iam-nat-role already
exists
  status code: 409, requestId: [e6812c4c-6fac-495c-be9d]
```

You get an error

Conclusion: Never make out-of-band changes.

2. AWS is eventually consistent

Terraform doesn’t always wait for a resource to propagate

Which causes a variety of intermittent bugs:

```
> terraform apply

...

* aws_route.internet-gateway:
error finding matching route for Route table (rtb-5ca64f3b)
and destination CIDR block (0.0.0.0/0)
```

```
> terraform apply

...

* Resource 'aws_eip.nat' does not have attribute 'id' for
variable 'aws_eip.nat.id'
```

```
> terraform apply

...

* aws_subnet.private-persistence.2: InvalidSubnetID.NotFound:
The subnet ID 'subnet-xxxxxxx' does not exist
```

```
> terraform apply

...

* aws_route_table.private-persistence.2:
InvalidRouteTableID.NotFound: The routeTable ID 'rtb-2d0d2f4a'
does not exist
```

```
> terraform apply
...
* aws_iam_instance_profile.instance_profile: diffs didn't
match during apply. This is a bug with Terraform and should be
reported.
* aws_security_group.asg_security_group_stg: diffs didn't
match during apply. This is a bug with Terraform and should be
reported.
```

The most generic one: diffs didn’t match during apply

Most of these are harmless. Just re-run `terraform apply`.

And try to run Terraform close to your AWS region (replica lag)

3. Avoid inline resources

```
resource "aws_route_table" "main" {
  vpc_id = "${aws_vpc.main.id}"

  route {
      cidr_block = "10.0.1.0/24"
      gateway_id = "${aws_internet_gateway.main.id}"
  }
}
```

Some resources allow blocks to be defined inline...

```
resource "aws_route_table" "main" {
  vpc_id = "${aws_vpc.main.id}"
}

resource "aws_route" "internet" {
  route_table_id = "${aws_route_table.main.id}"
  cidr_block = "10.0.1.0/24"
  gateway_id = "${aws_internet_gateway.main.id}"
}
```

Or in a **separate resource**

```
resource "aws_route_table" "main" {
  vpc_id = "${aws_vpc.main.id}"
}

resource "aws_route" "internet" {
  route_table_id = "${aws_route_table.main.id}"
  cidr_block = "10.0.1.0/24"
  gateway_id = "${aws_internet_gateway.main.id}"
}
```

Pick one technique or the other (separate resource is preferable)

```
resource "aws_route_table" "main" {
  vpc_id = "${aws_vpc.main.id}"
}

resource "aws_route" "internet" {
  route_table_id = "${aws_route_table.main.id}"
  cidr_block = "10.0.1.0/24"
  gateway_id = "${aws_internet_gateway.main.id}"
}
```

If you use both, you'll get confusing errors!

Affected resources:

- aws_route_table
- aws_security_group
- aws_elb
- aws_network_acl

4. Count interpolation

There is a significant **limitation** on the count parameter:

You cannot compute count from **dynamic data**

```
data "aws_availability_zones" "zones" {}

resource "aws_subnet" "public" {
  count = "${length(data.aws_availability_zones.zones.names)}"
  cidr_block = "${cidrsubnet(var.cidr_block, 5, count.index}"
  availability_zone =
    "${element(data.aws_availability_zones.zones.names,
               count.index)}"
}
```

Example: this code won't work

```
> terraform apply

...

* strconv.ParseInt: parsing
"${length(data.aws_availability_zones.zones.names)}": invalid
syntax
```

```
resource "aws_subnet" "public" {
  count = "${length(data.aws_availability_zones.zones.names)}"
  cidr_block = "${cidrsubnet(var.cidr_block, 5, count.index}"
  availability_zone =
    "${element(data.aws_availability_zones.zones.names,
               count.index)}"
}
```

`data.aws_availability_zones` **won't work since it fetches data**

```
resource "aws_subnet" "public" {
  count = 3
  cidr_block = "${cidrsubnet(var.cidr_block, 5, count.index}"
  availability_zone =
    "${element(data.aws_availability_zones.zones.names,
                count.index)}"
}
```

A fixed number is OK

```
resource "aws_subnet" "public" {
  count = "${var.num_availability_zones}"
  cidr_block = "${cidrsubnet(var.cidr_block, 5, count.index}"
  availability_zone =
    "${element(data.aws_availability_zones.zones.names,
               count.index)}"
}

variable "num_availability_zones" {
  default = 3
}
```

So is a hard-coded variable

For more info, see:

github.com/hashicorp/terraform/issues/3888

Outline

1. Intro
2. State
3. Modules
4. Best practices
5. Gotchas
6. Recap

Advantages of Terraform:

1. Define infrastructure-as-code
2. Concise, readable syntax
3. Reuse: inputs, outputs, modules
4. Plan command!
5. Cloud agnostic
6. Very active development

Disadvantages of Terraform:

1. Maturity. You will hit bugs.
2. Collaboration on Terraform state is tricky (but not with terragrunt)
3. No rollback
4. Poor secrets management

Questions?

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