(not for Dummies)

Agenda

Introduction

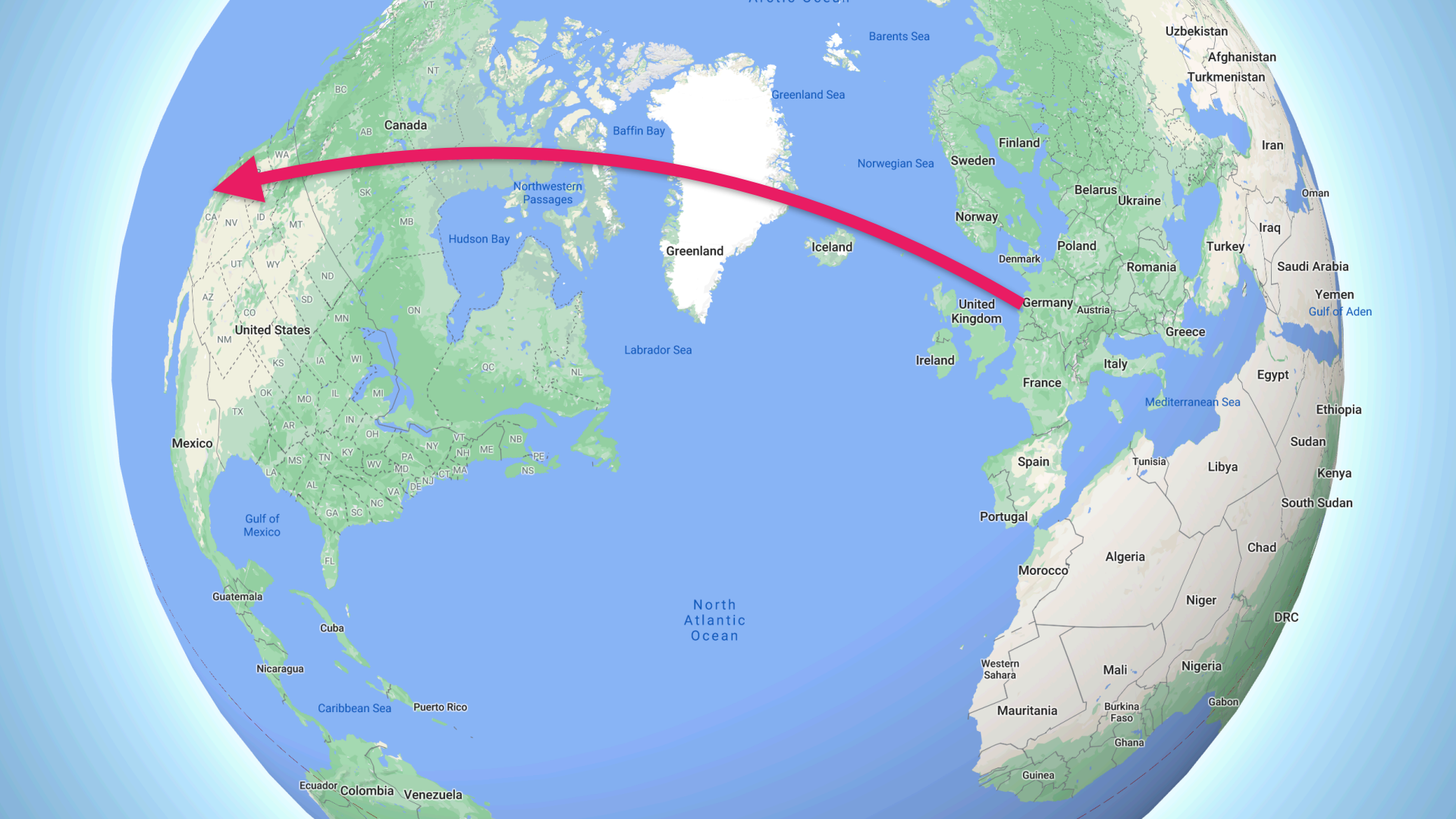
How to write fast code

Flecs Basics

Flecs Advanced

Flecs in Practice

Introduction


Barents Sea
Greenland Sea
Baffin Bay
Norwegian Sea
Northwestern Passages
Hudson Bay
Labrador Sea
North Atlantic Ocean
Gulf of Mexico
Caribbean Sea
Canada
United States
Mexico
Greenland
Iceland
Ireland
United Kingdom
Norway
Sweden
Finland
Belarus
Ukraine
Poland
Denmark
Germany
Austria
Romania
Greece
Italy
France
Spain
Portugal
Morocco
Algeria
Tunisia
Libya
Egypt
Mediterranean Sea
Uzbekistan
Afghanistan
Turkmenistan
Iran
Iraq
Turkey
Oman
Saudi Arabia
Yemen
Gulf of Aden
Ethiopia
Sudan
Kenya
South Sudan
Chad
Niger
DRC
Nigeria
Mali
Western Sahara
Mauritania
Burkina Faso
Ghana
Gabon
Guinea
Guatemala
Cuba
Nicaragua
Puerto Rico
Ecuador
Colombia
Venezuela


ONTARIO
NB
PE
NOVA SCOTIA
MAINE
Ottawa
WASHINGTON
MONTANA
NORTH DAKOTA
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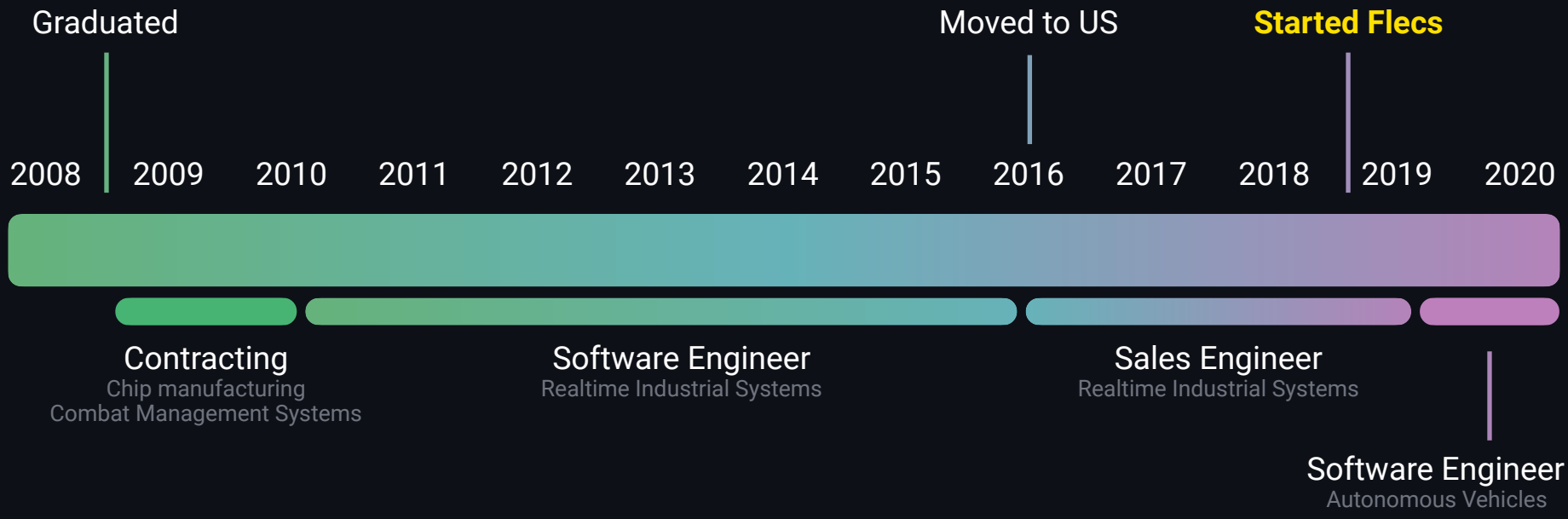
OREGON
IDAHO
SOUTH DAKOTA
MICHIGAN
NEW YORK
RI
WYOMING
Chicago
PENN
Philadelphia
IOWA
ILLINOIS
OHIO
DE
NEBRASKA
NEVADA
San Francisco
UTAH
United States
WEST VIRGINIA
KANSAS
MISSOURI
KENTUCKY
CALIFORNIA
NORTH CAROLINA
Las Vegas
TENNESSEE
Los Angeles
OKLAHOMA
SOUTH CAROLINA
ARIZONA
MISSISSIPPI
NEW MEXICO
Dallas
GEORGIA
TEXAS
LOUISIANA
Houston
FLORIDA
Gulf of California
Gulf of Mexico
Dominican Republic
Puerto Rico
Cuba
Mexico
Mexico City
Caribbean Sea
Caracas

Introduction

Timeline



Introduction

Project Overview

Unwatch 50 | Star 1.5k | Fork 105

C99 CORE HIGH PERFORMANCE

C++11 API PORTABLE

OPTIONAL ADDONS LOW FOOTPRINT

MODULE ECOSYSTEM PROMOTES REUSABILITY

ZERO DEPENDENCIES EASY TO USE

Introduction

High Level Concepts

STORAGE Store entities, components, relationships

QUERIES Expression that matches components

SYSTEMS Which code do I run for matched data

PIPELINES When do I run systems

MODULES How are systems & components organized

Introduction

Unique Features

HIERARCHIES Store & query hierarchies natively

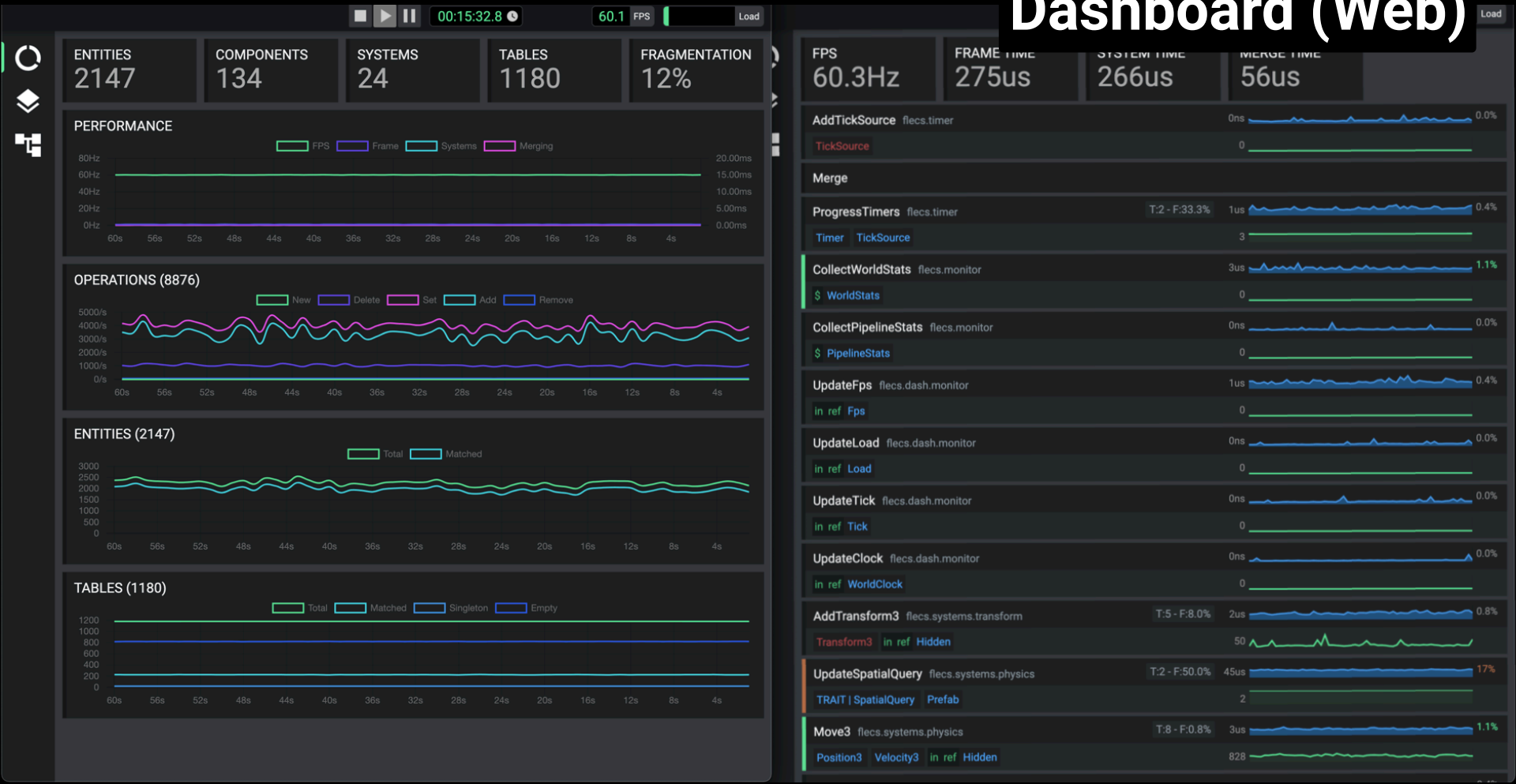
RELATIONSHIPS Store & query relationships natively

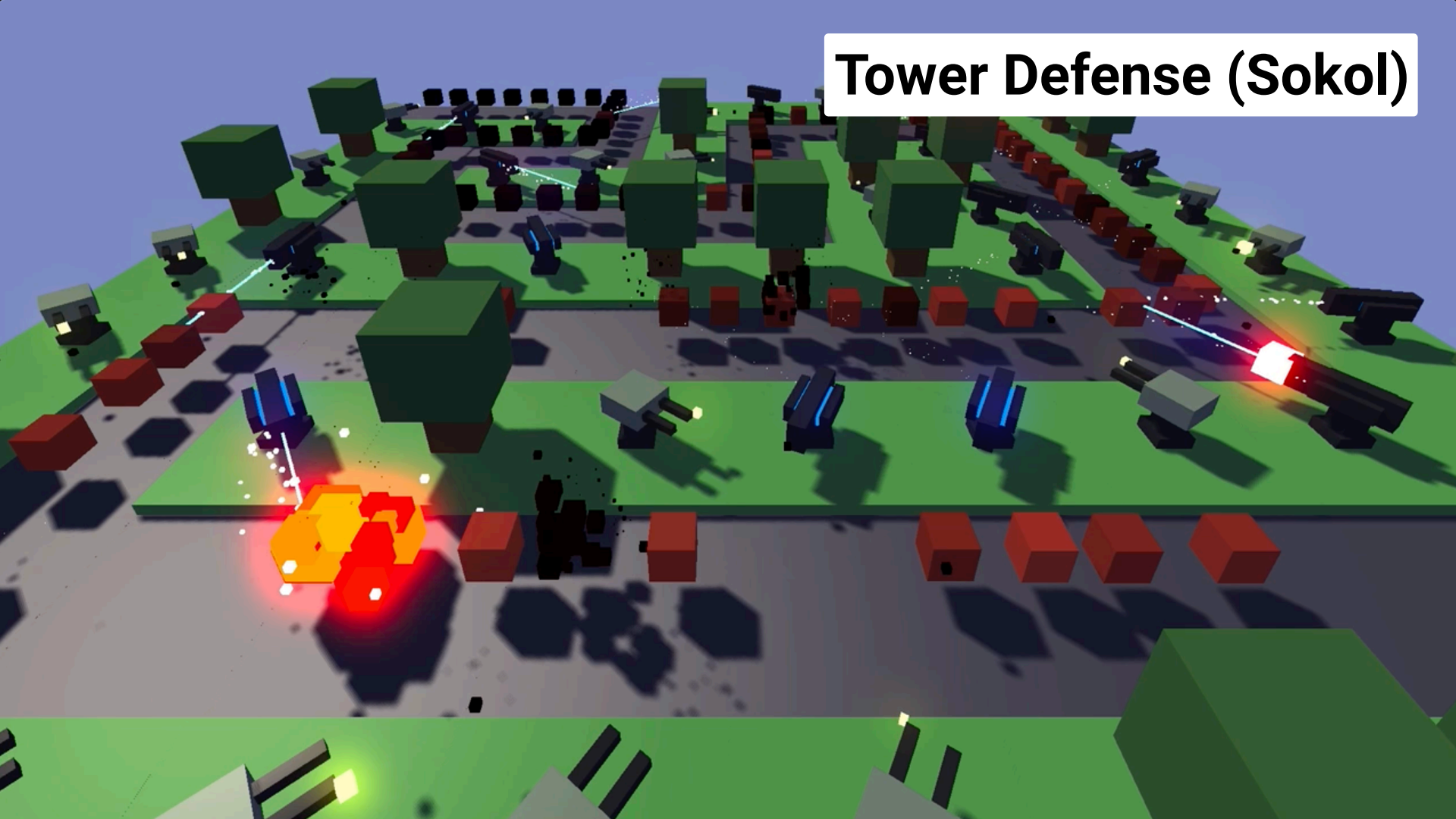
PREFABS Create & instantiate entity templates

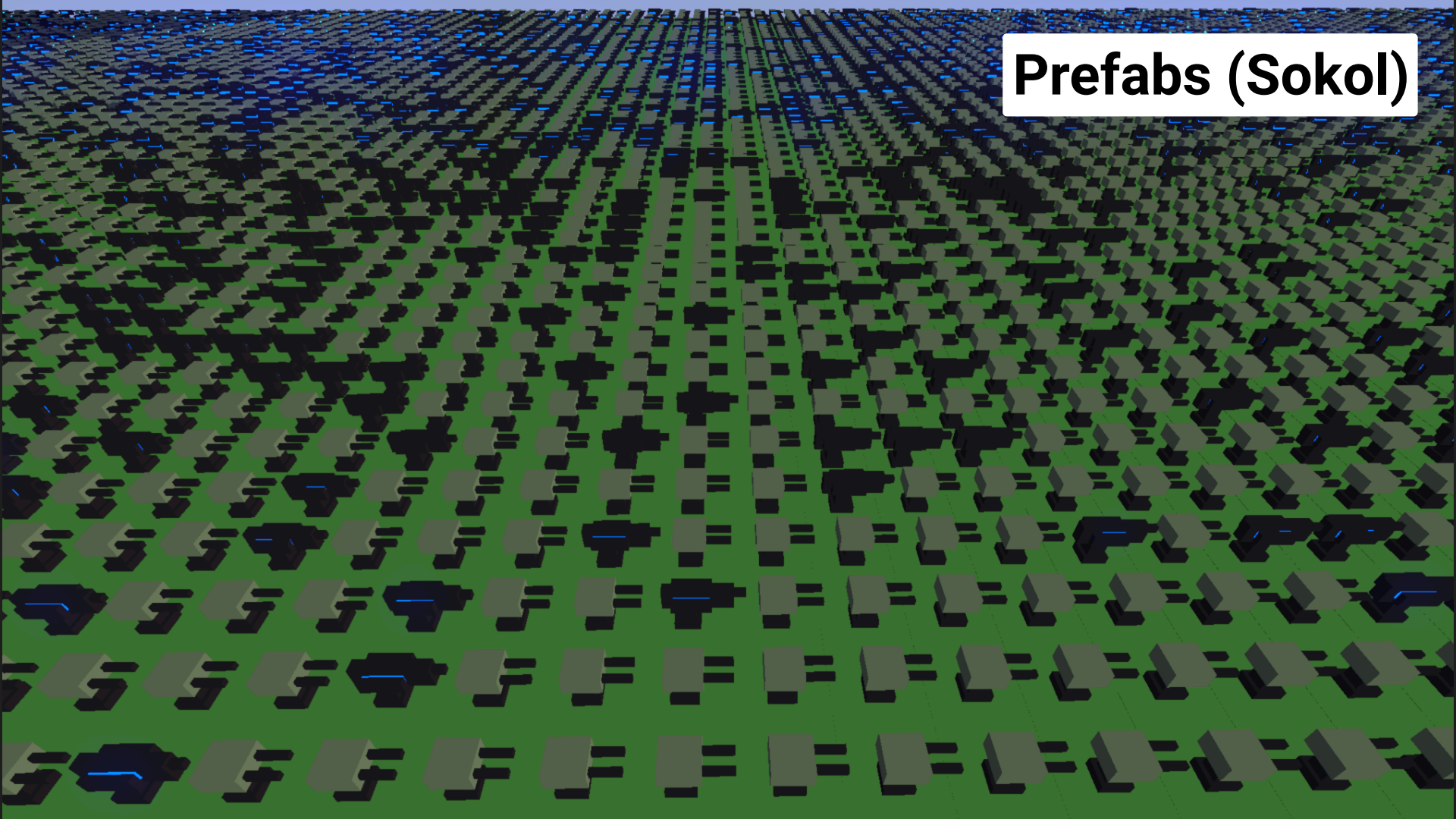
THREADING Thread-safe command queue

TOOLING Statistics, dashboard, reflection

Dashboard (Web)




Tower Defense (Sokol)


Prefabs (Sokol)


Voxels (Sokol)

Introduction

Community

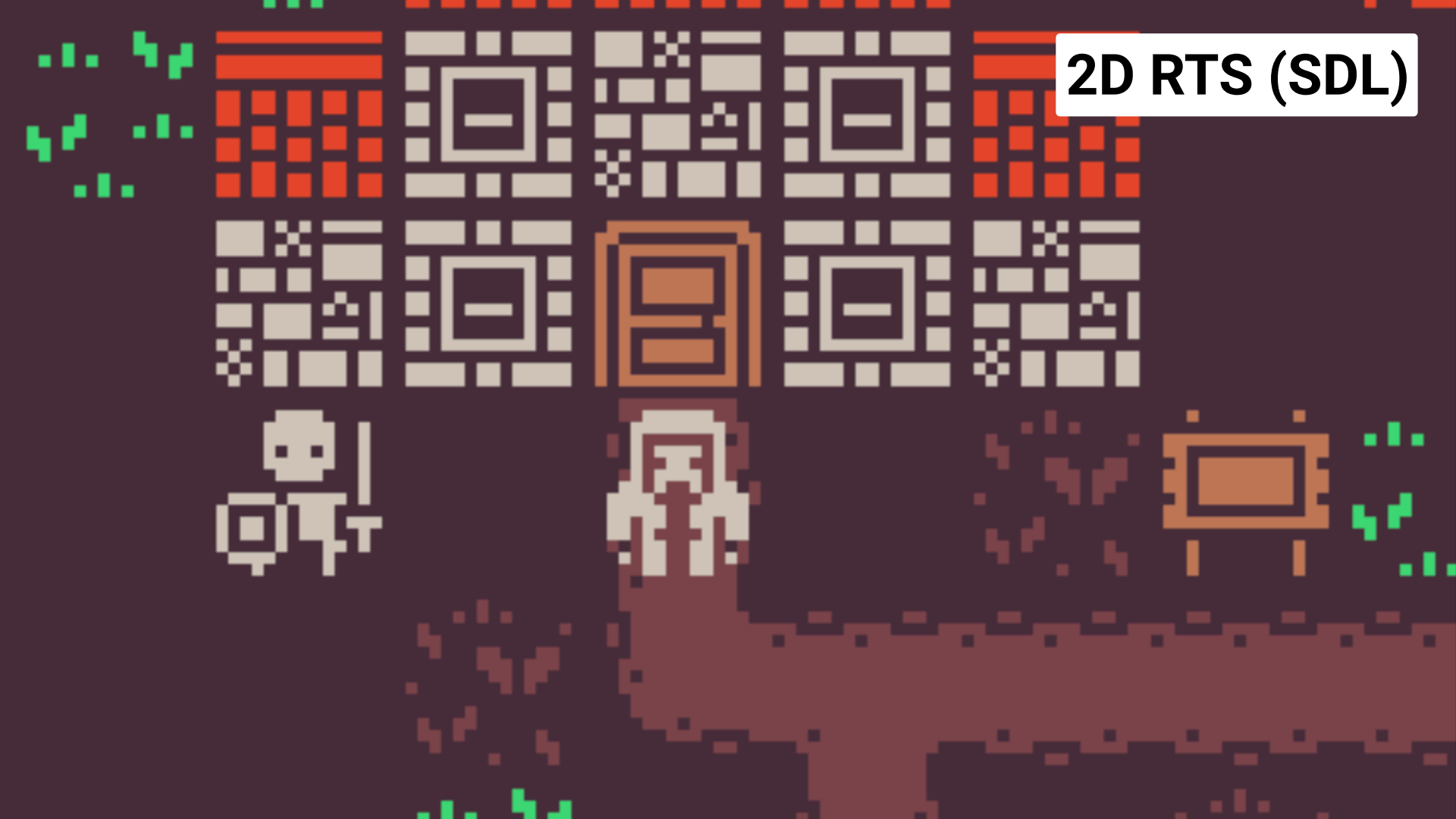
23 CONTRIBUTORS

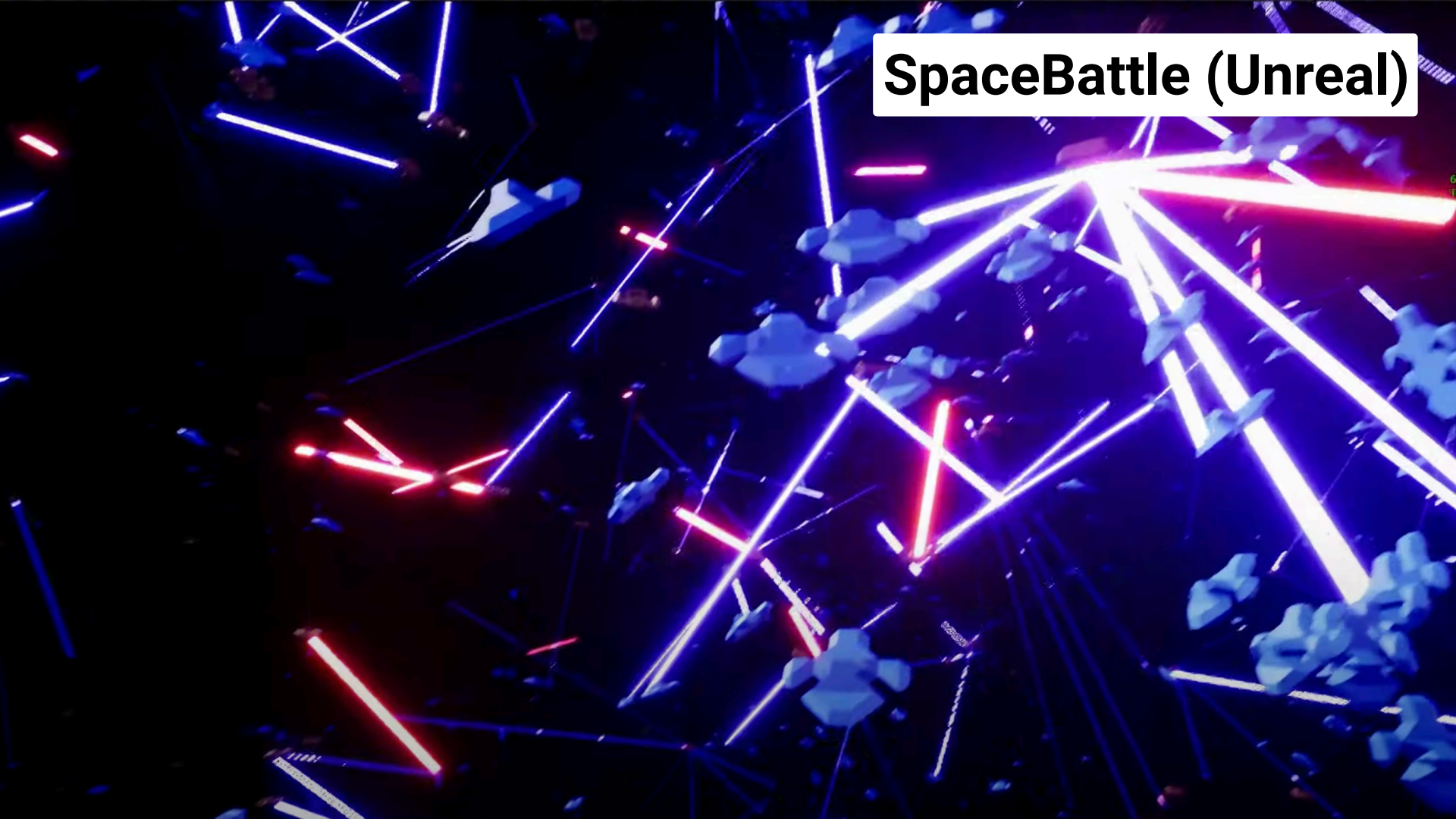
117 PULL REQUESTS

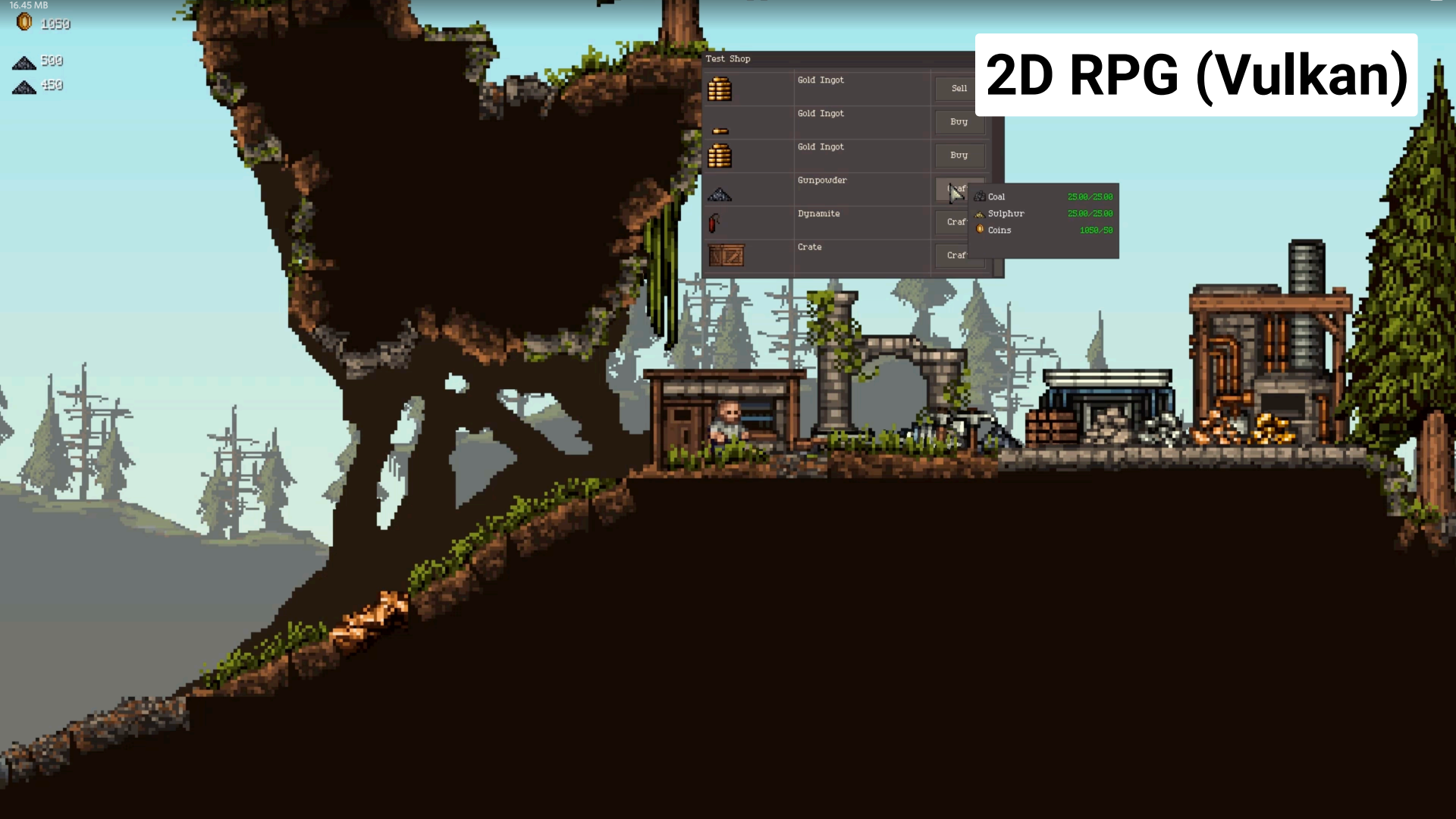
105 FORKS

~400 DISCORD MEMBERS

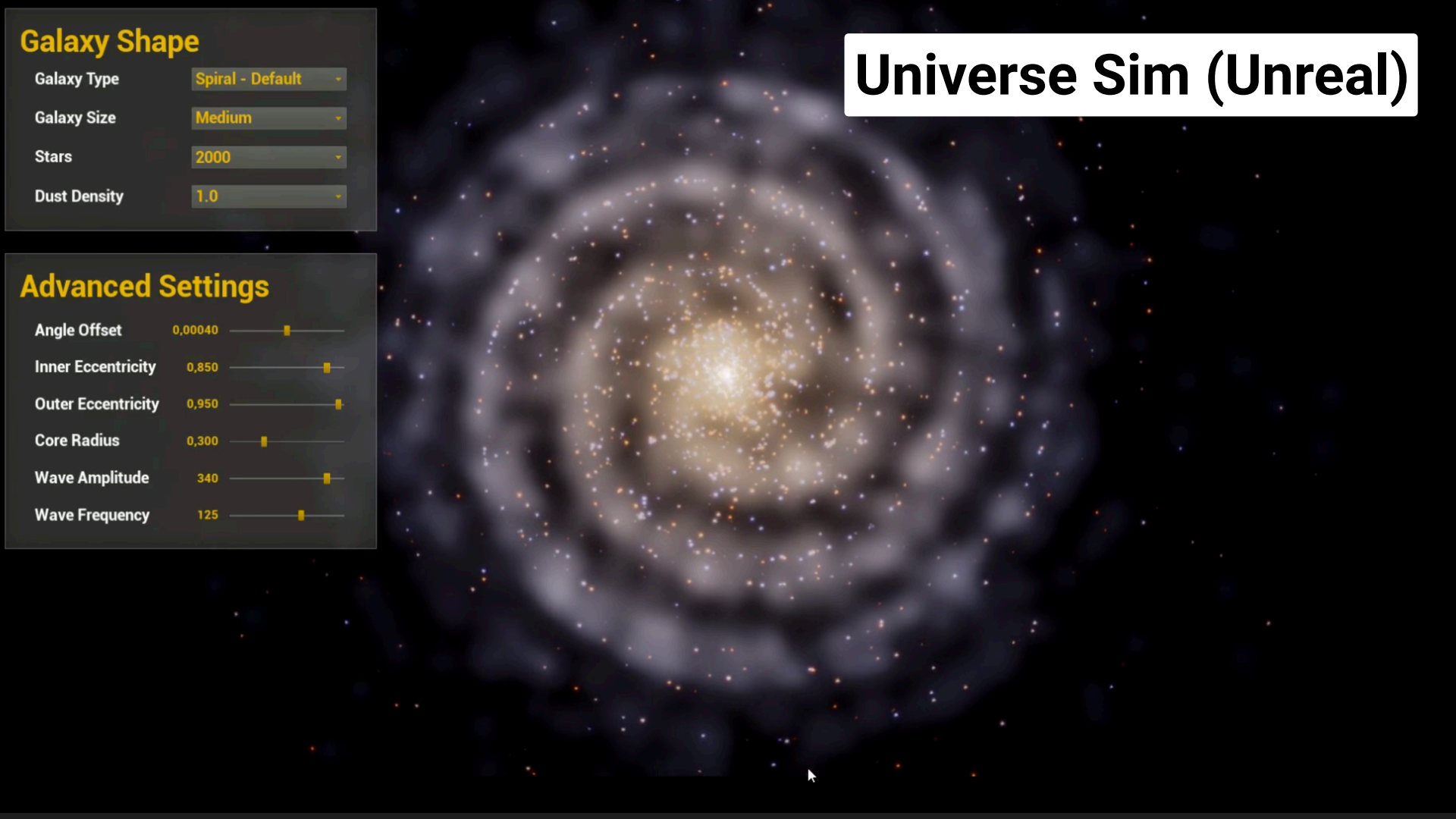
COMMERCIALLY USED

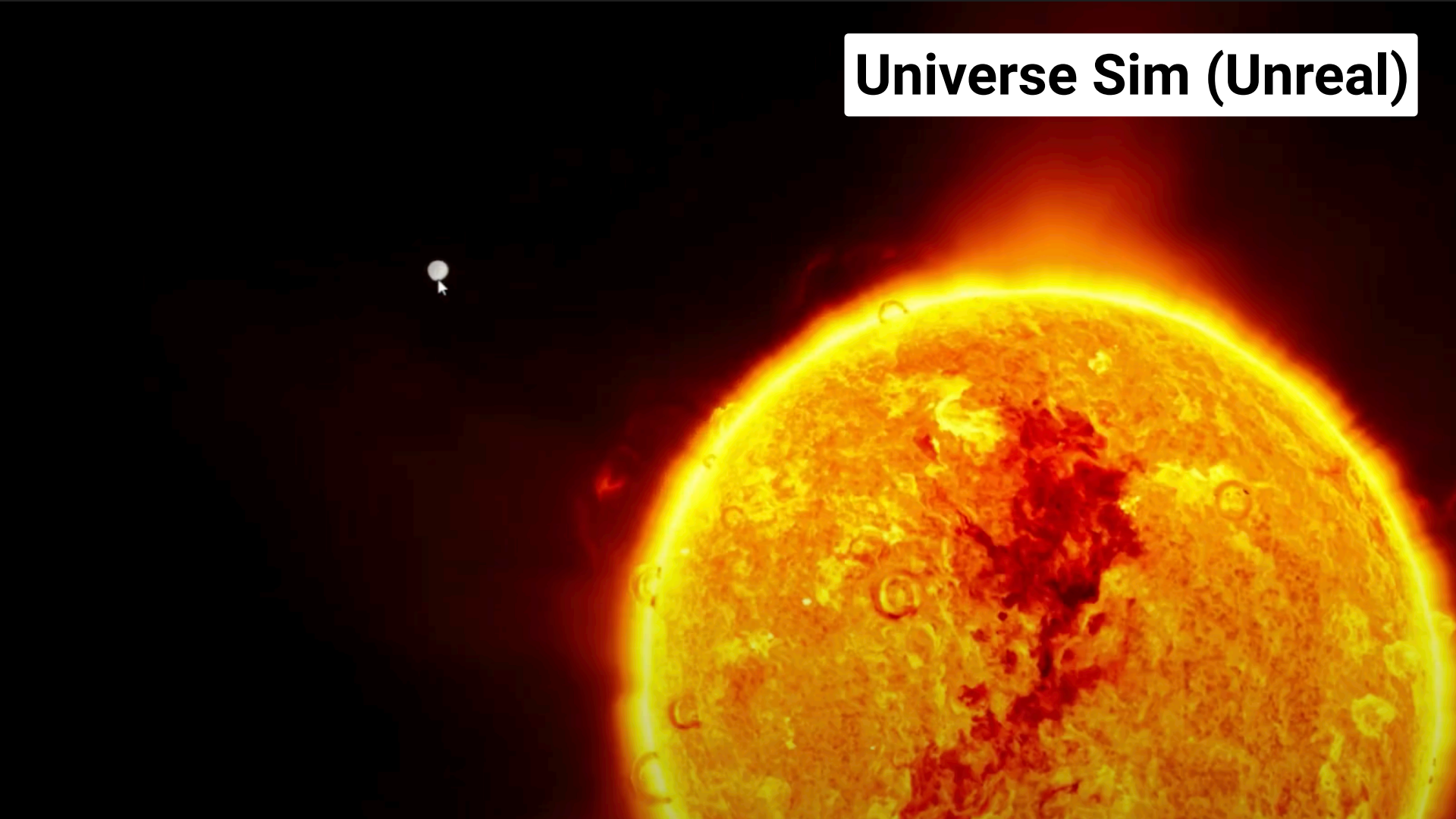

2D RTS (SDL)


SpaceBattle (Unreal)


16.45 MB
1050
500
450
Test Shop
Gold Ingot
Sell
Gold Ingot
Buy
Gold Ingot
Buy
Gunpowder
Dynamite
Crate
Coal 25.00/25.00
Sulphur 25.00/25.00
Coins 1050/50
2D RPG (Vulkan)


15.77 MB
1990
2D RPG (Vulkan)


Galaxy Shape
Galaxy Type
Spiral - Default
Galaxy Size
Medium
Stars
2000
Dust Density
1.0
Advanced Settings
Angle Offset
0,00040
Inner Eccentricity
0,850
Outer Eccentricity
0,950
Core Radius
0,300
Wave Amplitude
340
Wave Frequency
125
Universe Sim (Unreal)


Universe Sim (Unreal)

Universe Sim (Unreal)

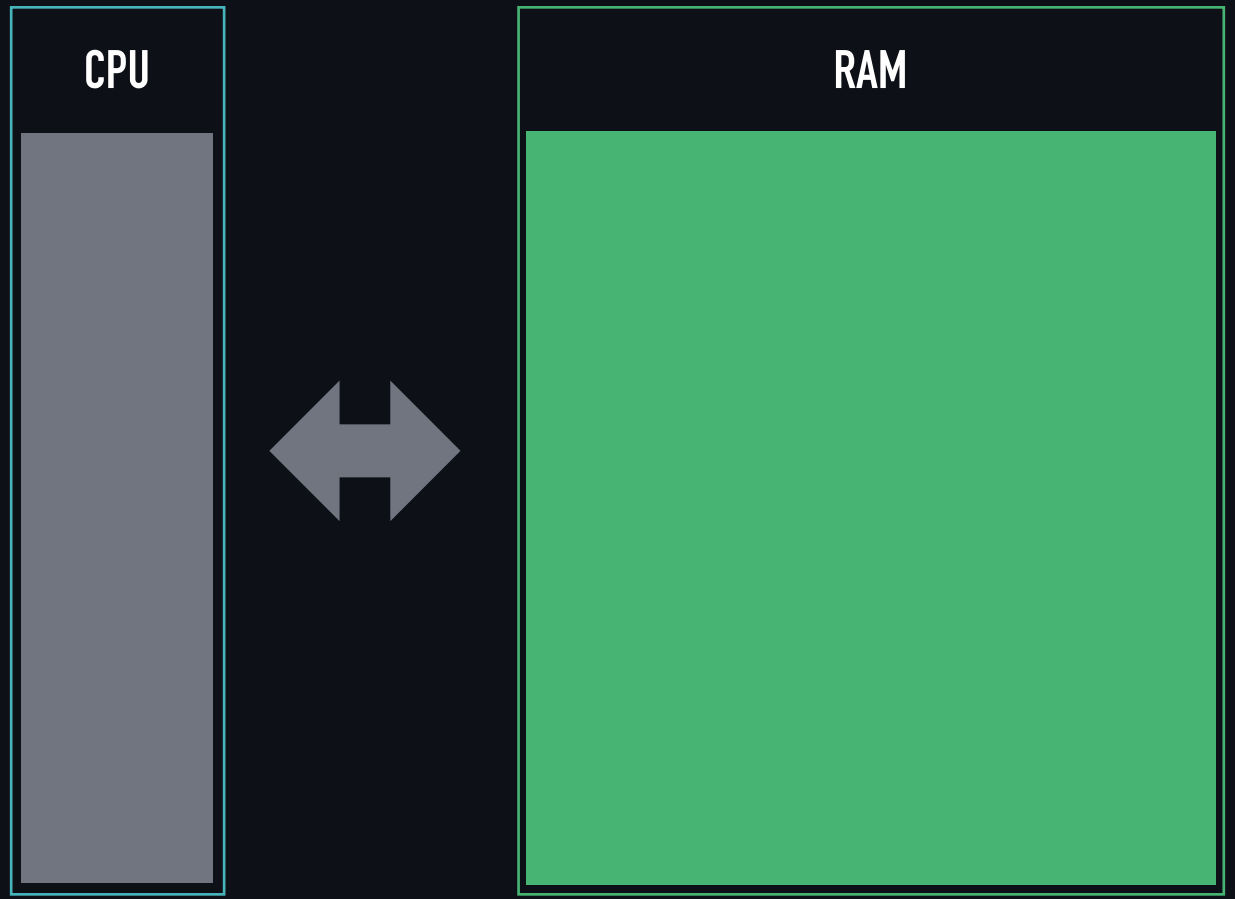

bebylon
BATTLE ROYALE
Battle Royale (Unreal)

Writing Fast Code

Storage

Writing Fast Code

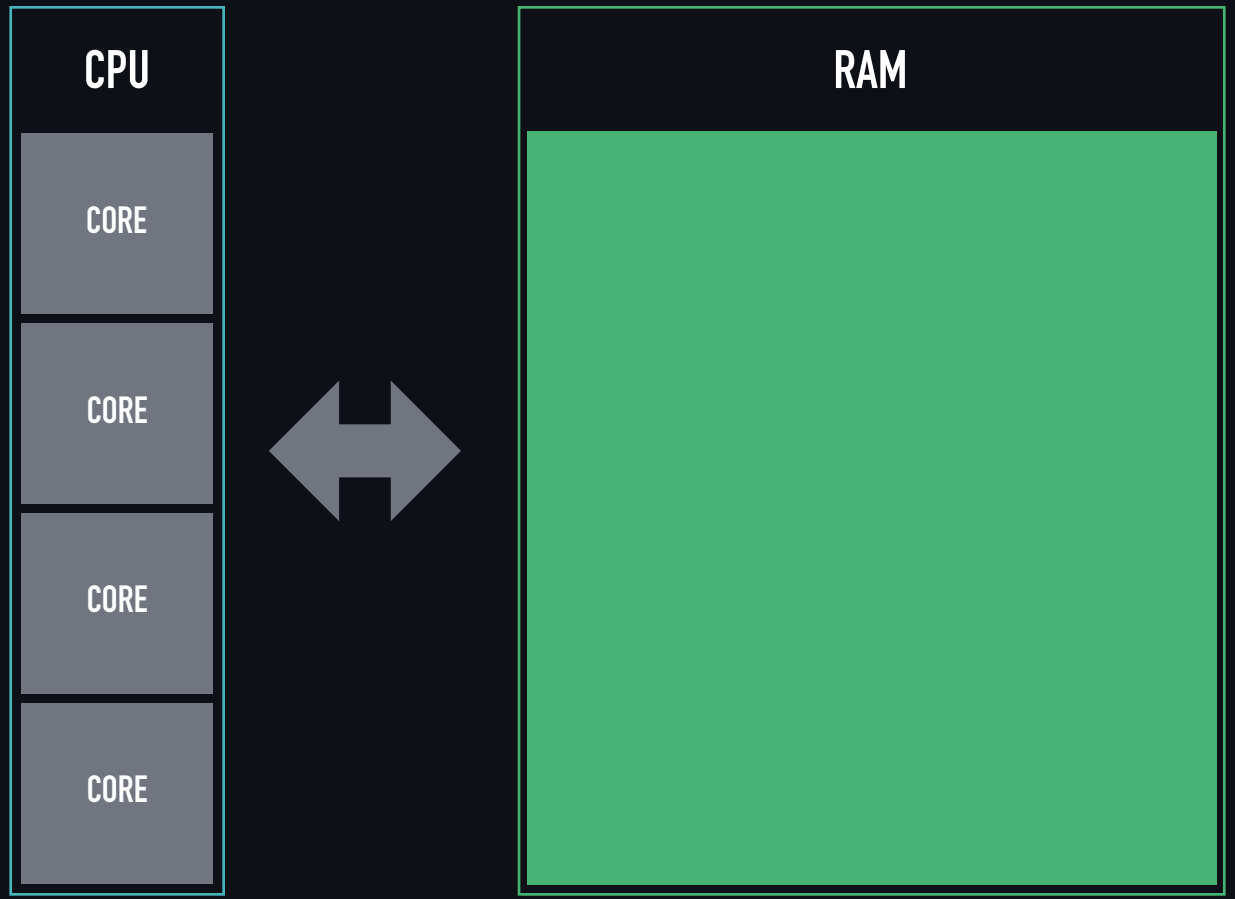
Storage



CPU fetches & stores data from RAM when running code.

Writing Fast Code

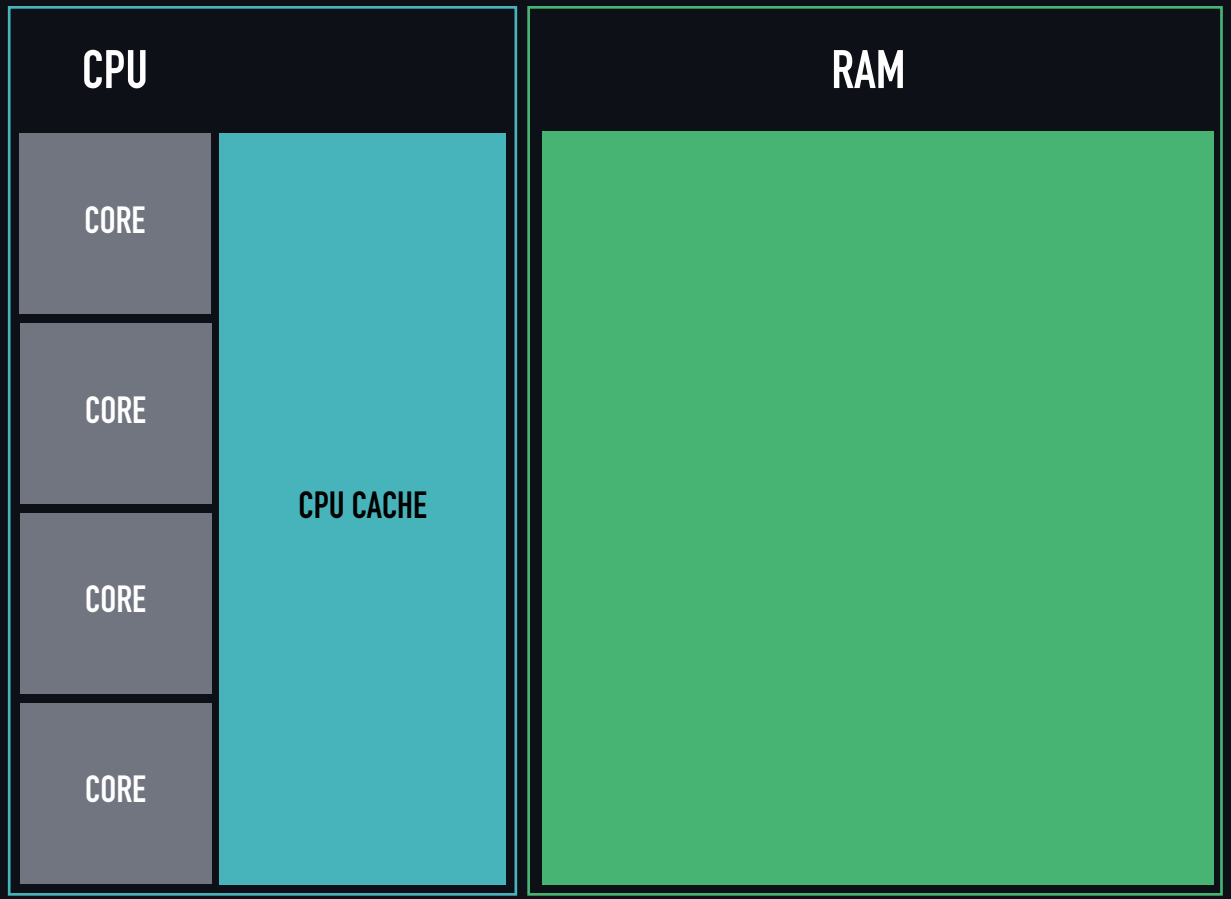
Storage



A single CPU can have many cores.

Writing Fast Code

Storage



Data fetched from RAM is temporarily stored in a local CPU cache

Writing Fast Code

Storage

Each core has its own L1 and L2 cache, with a shared L3 cache

Writing Fast Code

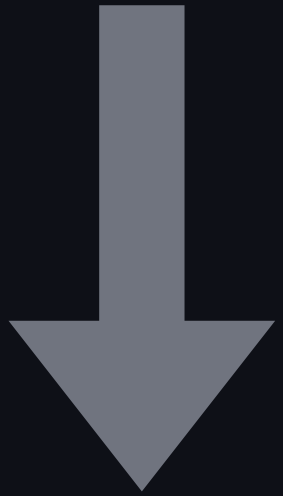
Storage

There is a LOT more
RAM than there is space
in the CPU cache

Writing Fast Code

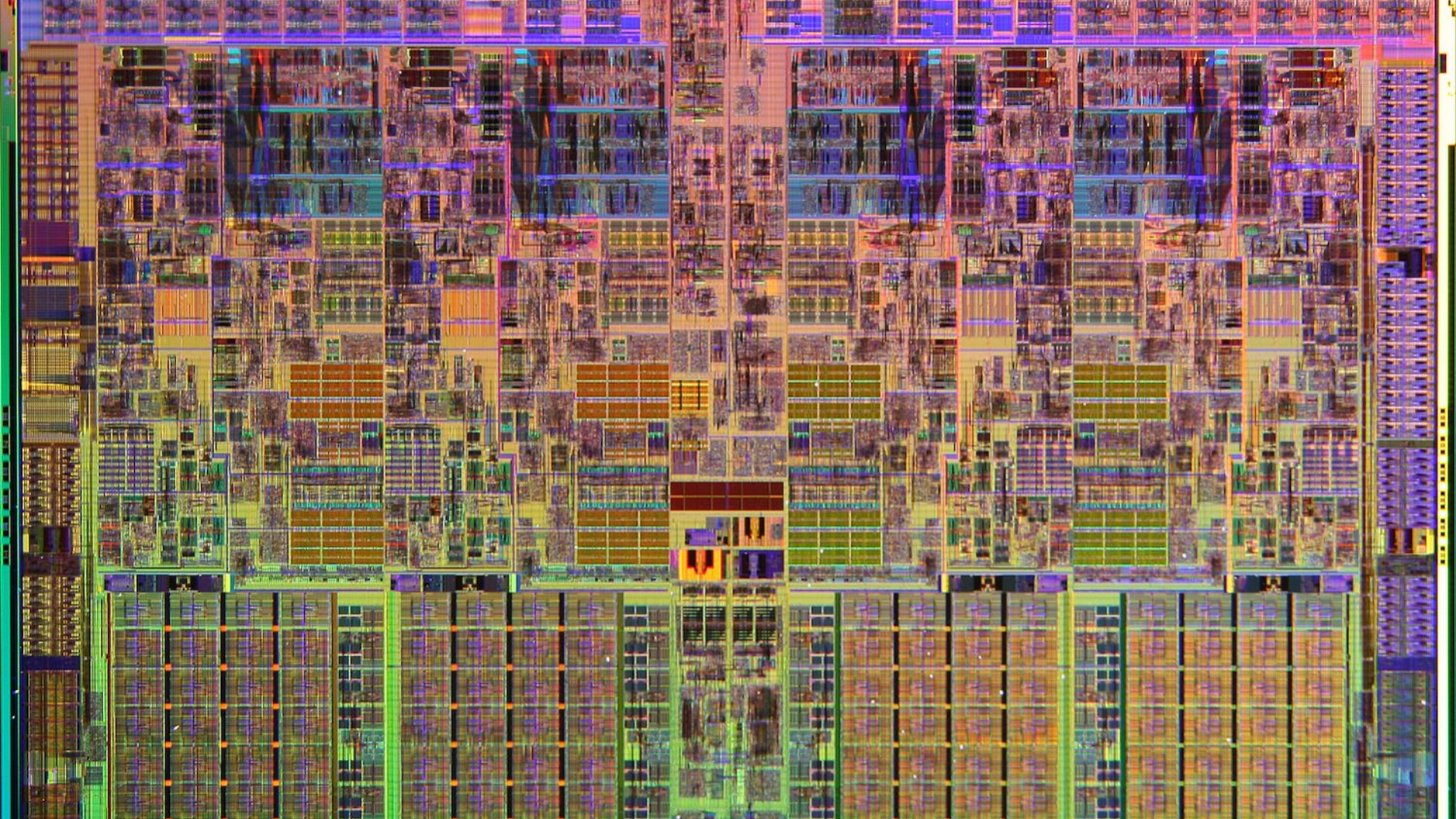
Storage

There is a LOT more disk space than RAM



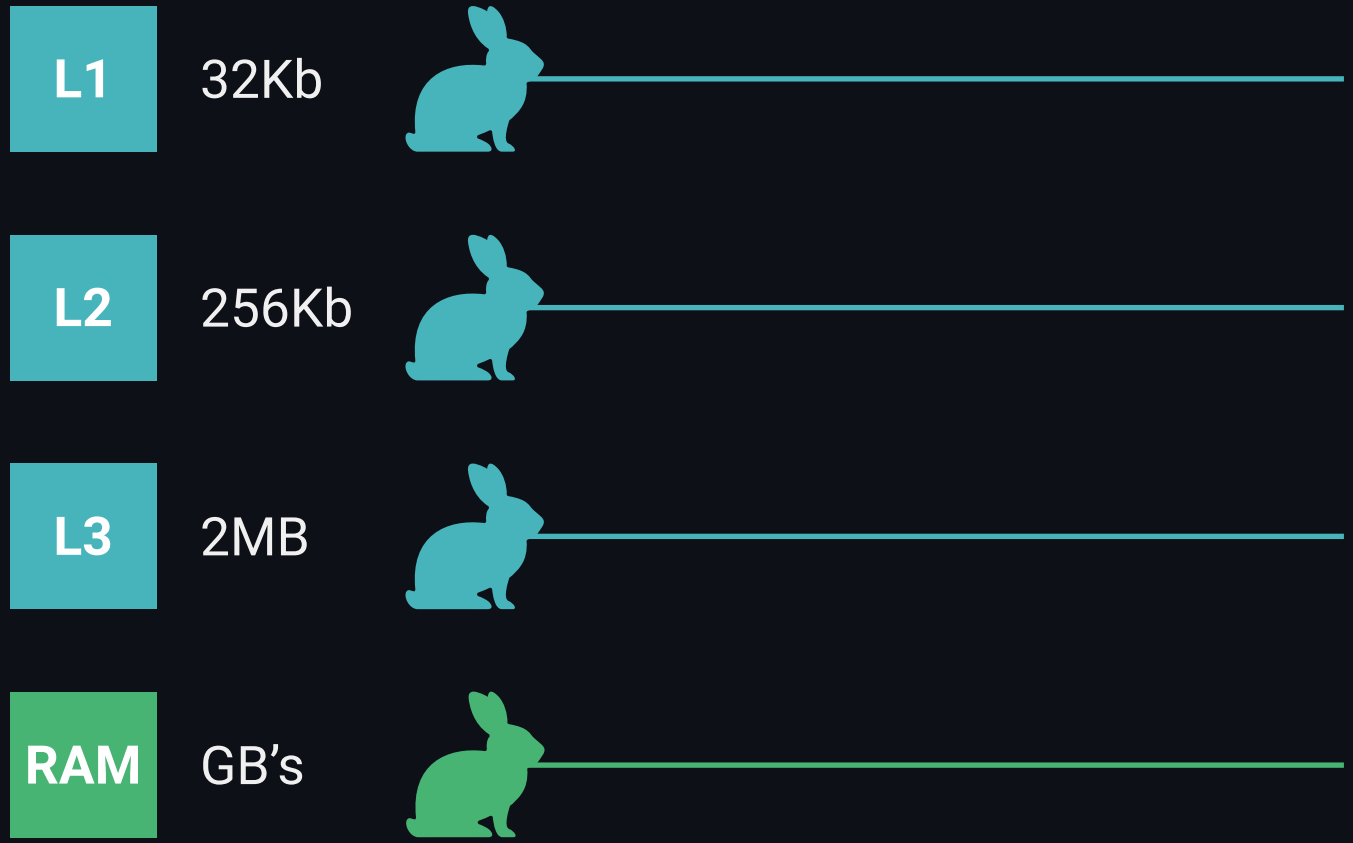
CPU

RAM



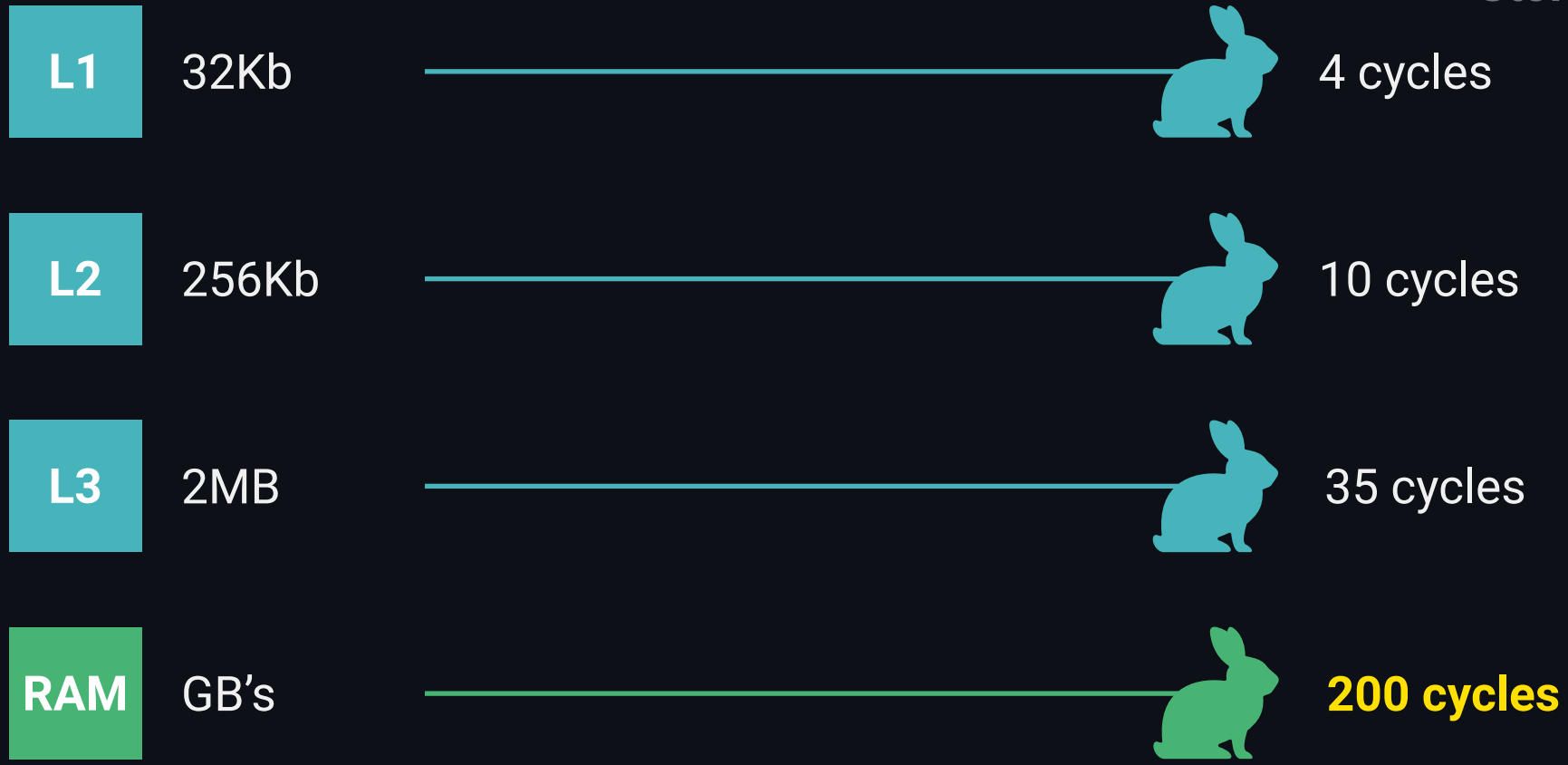
Writing Fast Code

Storage



Writing Fast Code

Storage



Writing Fast Code

Storage

Why do we not just make RAM that is as fast as a CPU cache? Three reasons:

COST

ENERGY USAGE

PHYSICS

Cache Lines

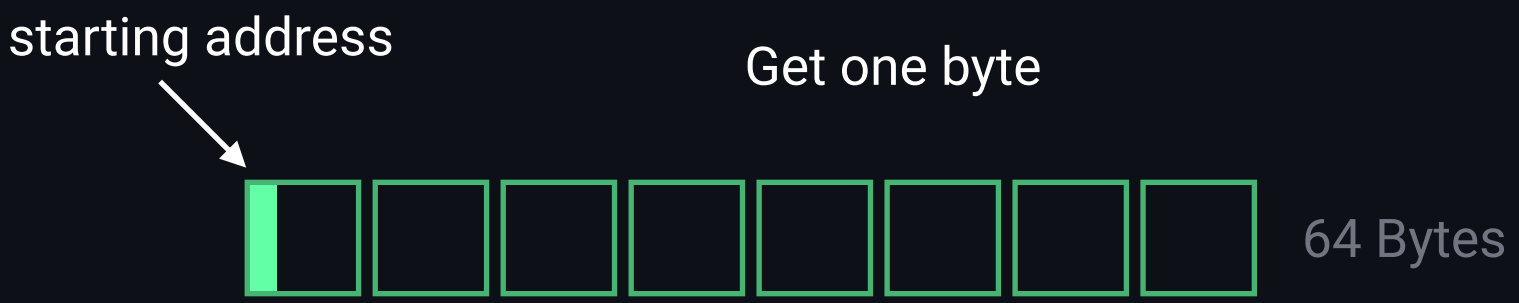
Writing Fast Code

Cache Lines

64 Bytes

Writing Fast Code

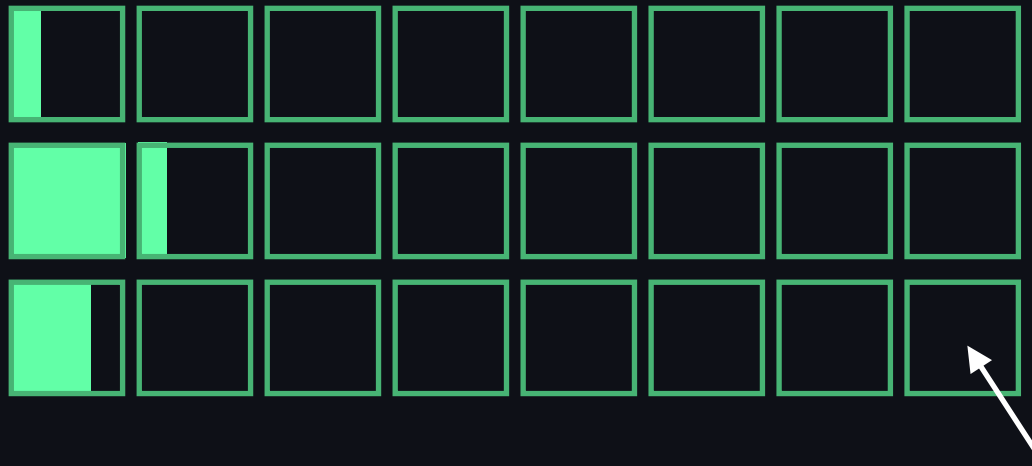
Cache Lines



Writing Fast Code

Cache Lines

Get some bytes from different pointers (aka OOP)



Sad cache :(

lots of wasted space

Writing Fast Code

Cache Lines

If the cache is full, old data is evicted

Writing Fast Code

Cache Lines

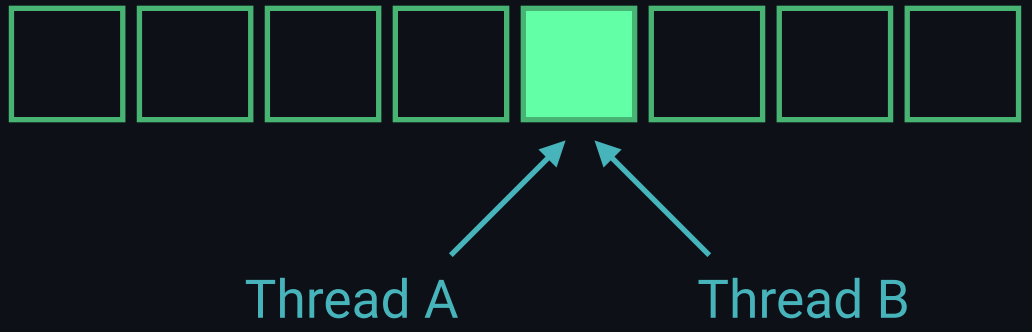
Fetching arrays loads more useful data, reducing RAM roundtrips

Happy cache :)

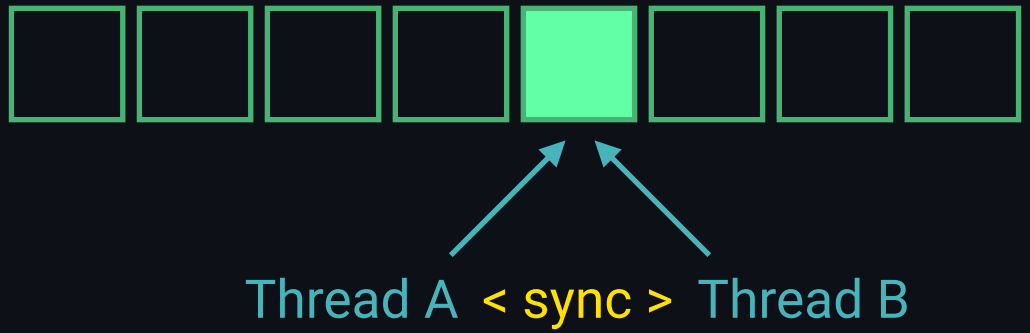
no wasted space

Multithreading

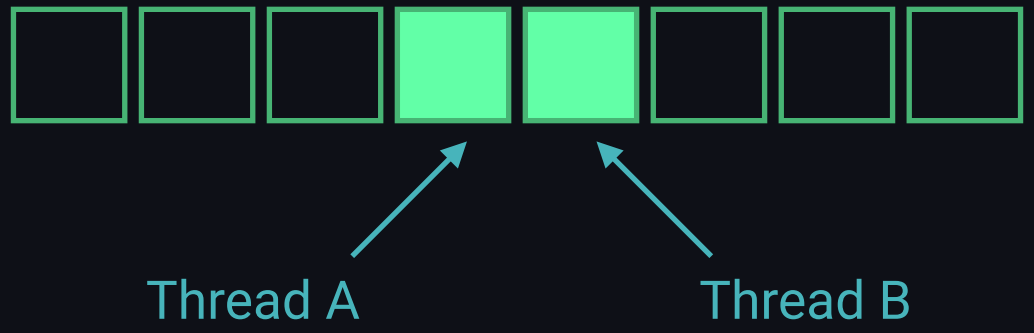
What about threads?



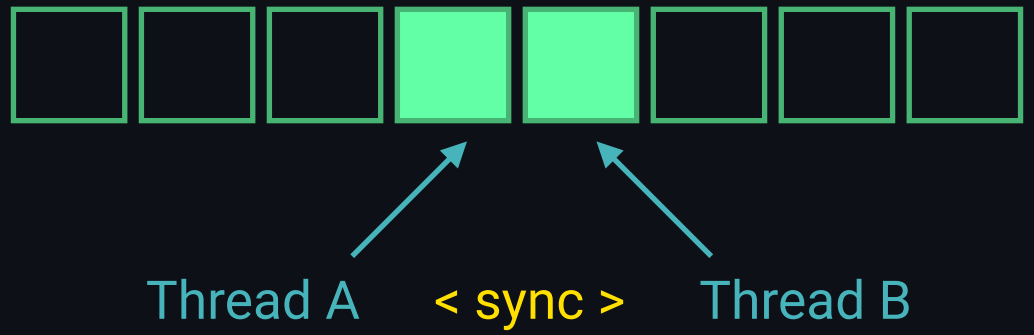
Threads are on different cores, so L1/L2 caches must be synced



What if the data is on 2 separate addresses?



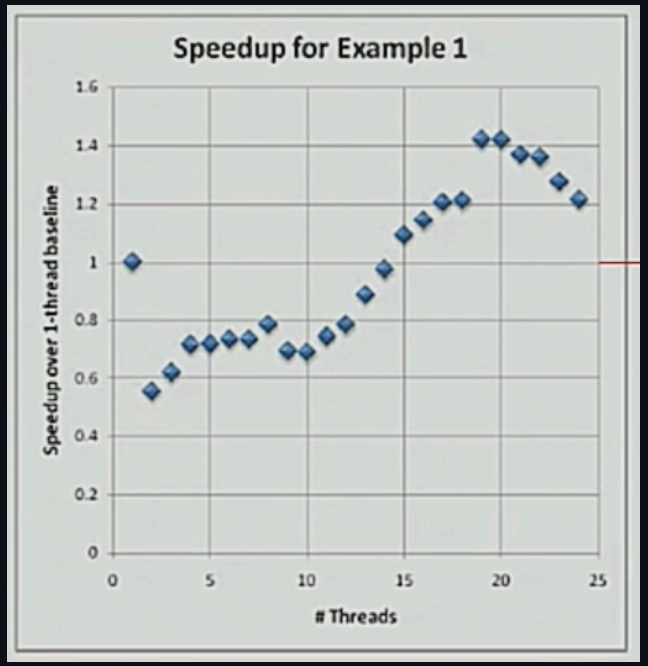
Sync still happens inside the same cache line. This is called False Sharing



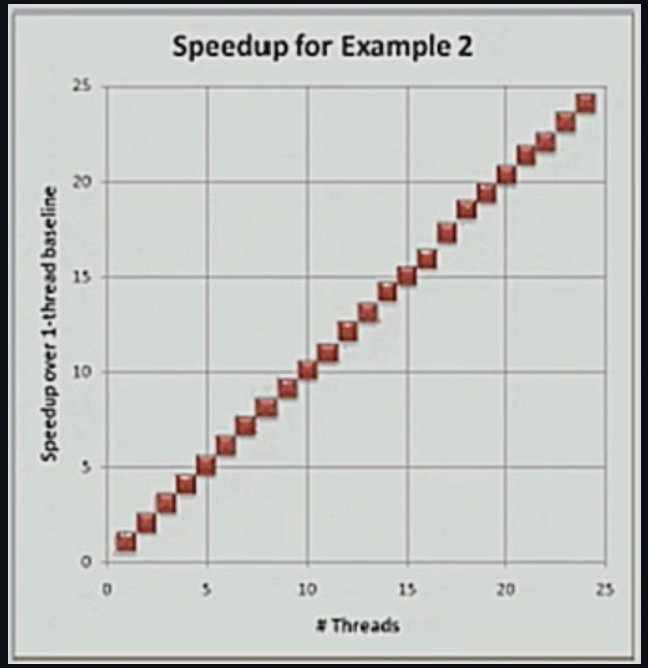
Writing Fast Code

Multithreading

False Sharing



No False Sharing



Scott Meyers - CPU caches and why you care: https://vimeo.com/97337258

Data Oriented Design

Writing Fast Code

Data Oriented Design

Data Oriented Design is about processing data in a way that takes advantage of capabilities of the underlying hardware, such as:

CACHING

VECTORIZATION

THREADING

Writing Fast Code

Data Oriented Design

```
struct Wizard {
    float x;
    float y;
    float health;
    float mana;
}

Wizard *wizards[1000];

for (int i = 0; i < 1000; i ++) {
    wizards[i]->x ++;
    wizards[i]->y ++;
}
```

Bad data oriented design™

Writing Fast Code

Data Oriented Design

```
for (int i = 0; i < 1000; i ++) {
    wizards[i]->x ++;
    wizards[i]->y ++;
}
```

Writing Fast Code

Data Oriented Design

```
// Thread 1
for (int i = 0; i < 1000; i ++) {
    wizards[i]->x ++;
    wizards[i]->y ++;
}

// Thread 2
for (int i = 0; i < 1000; i ++) {
    wizards[i]->health ++;
}
```

False Sharing

False Sharing

Writing Fast Code

Data Oriented Design

Writing Fast Code

Data Oriented Design

```
struct Wizard {
    float x;
    float y;
    float attack;
    float health;
}

Wizard *wizards = new Wizard[1000];

for (int i = 0; i < 1000; i ++) {
    wizards[i].x ++;
    wizards[i].y ++;
}
```

Better data oriented design™

This approach is called
Arrays of Structs (AoS)

Writing Fast Code

Data Oriented Design

```
for (int i = 0; i < 1000; i ++) {
    wizards[i].x ++;
    wizards[i].y ++;
}
```

No cache miss

Writing Fast Code

Data Oriented Design

```
// Thread 1
for (int i = 0; i < 1000; i ++) {
    wizards[i].x ++;
    wizards[i].y ++;
}

// Thread 2
for (int i = 0; i < 1000; i ++) {
    wizards[i].health ++;
}
```

Still got false Sharing

Still got false Sharing

Writing Fast Code

Data Oriented Design

Writing Fast Code

Data Oriented Design

```
struct Wizards {
    float x[1000];
    float y[1000];
    float attack[1000];
    float health[1000];
}

Wizards *wizards = new Wizards();

for (int i = 0; i < 1000; i ++) {
    wizards.x[i] ++;
    wizards.y[i] ++;
}
```

Good data oriented design™

This approach is called
Struct of Arrays (SoA)

Writing Fast Code

Data Oriented Design

```
for (int i = 0; i < 1000; i ++) {
    wizards.x[i] ++;
    wizards.y[i] ++;
}
```

No cache miss

Writing Fast Code

Data Oriented Design

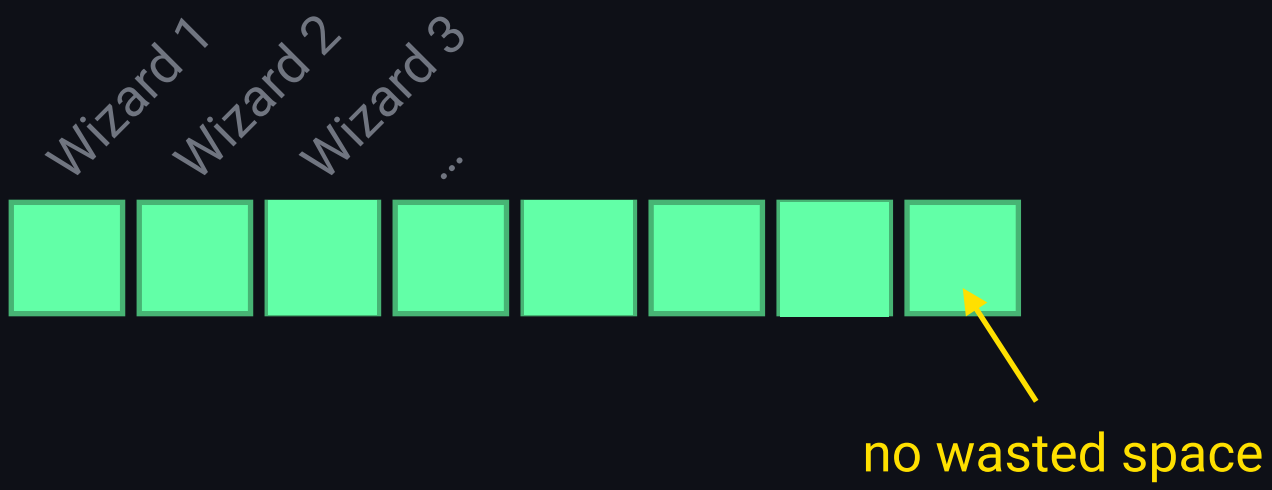
```
// Thread 1
for (int i = 0; i < 1000; i ++) {
    wizards.x[i] ++;
    wizards.y[i] ++;
}

// Thread 2
for (int i = 0; i < 1000; i ++) {
    wizards.health[i] ++;
}
```

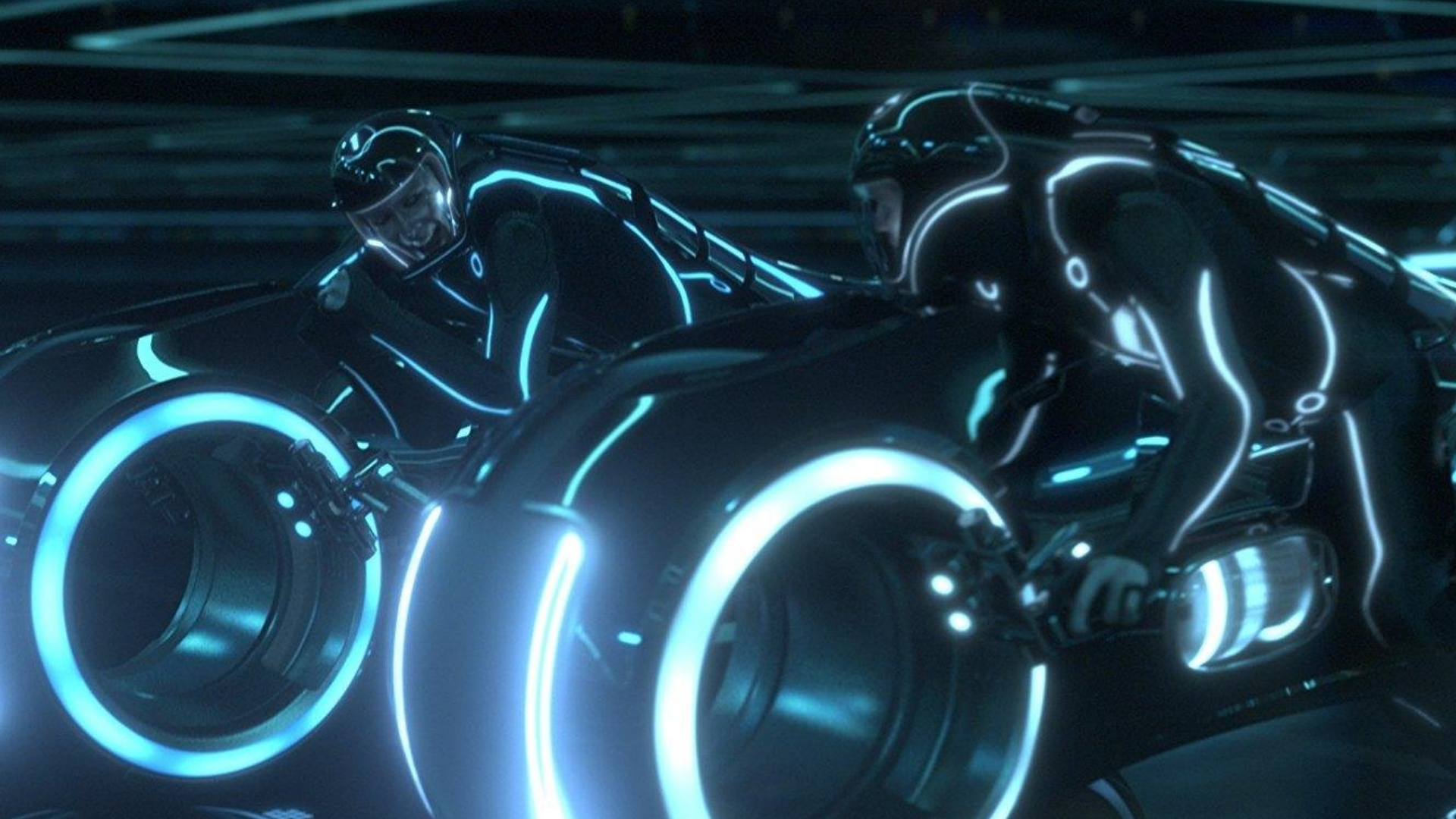
No false Sharing

No false Sharing

Writing Fast Code

Data Oriented Design





Writing Fast Code

ECS

Writing Fast Code

ECS

ECS is a tool that (amongst others) helps us write data oriented code.

Writing Fast Code

ECS

ECS is a tool that (amongst others) helps us write data oriented code.

ECS is NOT performance by default!

ECS is a tool that (amongst others) helps us write data oriented code.

ECS is NOT performance by default!

To realize the benefits of ECS, code has to be structured in a way that is very different from OOP.

Flecs Basics

Entities, Types, Components

Flecs Basics

Entities, Types, Components

Flecs is an Entity Component System

Flecs Basics

Entities, Types, Components

Flecs is an Entity ~~Component~~ System

Flecs Basics

Entities, Types, Components

Flecs is an Entity Relationship System

(but behaves like a regular ECS most of the time)

Flecs Basics

Entities, Types, Components

Flecs is an Entity Relationship System

(but behaves like a regular ECS most of the time)

Let’s take a look at how that works

Flecs Basics

Entities, Types, Components

An entity in Flecs is a unique integer

Flecs Basics

Entities, Types, Components

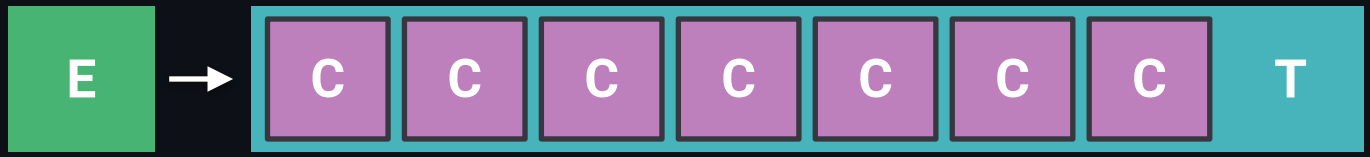
Flecs Basics

Entities, Types, Components

A type is a set (stored as an array) of identifiers

Flecs Basics

Entities, Types, Components



These identifiers indicate which components an entity has

Flecs Basics

Entities, Types, Components

Components are associated with datatypes

Flecs Basics

Entities, Types, Components

Flecs has “add” and “remove” operations that add & remove identifiers to a type

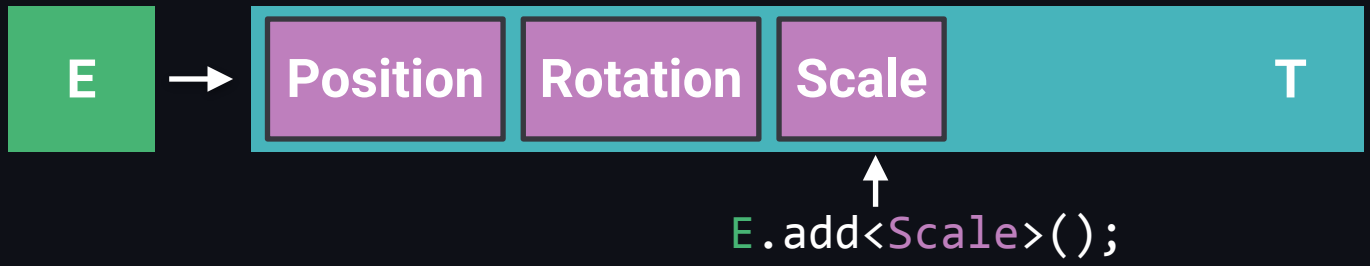
Flecs Basics

Entities, Types, Components

Flecs has “add” and “remove” operations that add & remove identifiers to a type

Flecs Basics

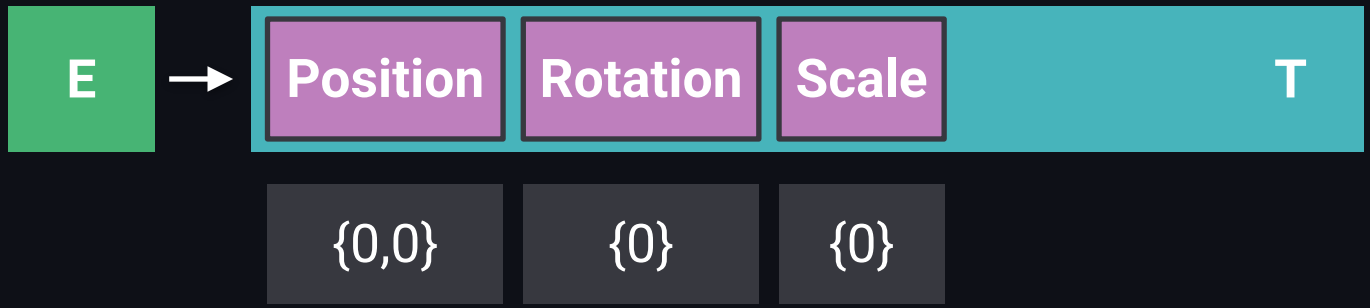
Entities, Types, Components



Flecs has “add” and “remove” operations that add & remove identifiers to a type

Flecs Basics

Entities, Types, Components

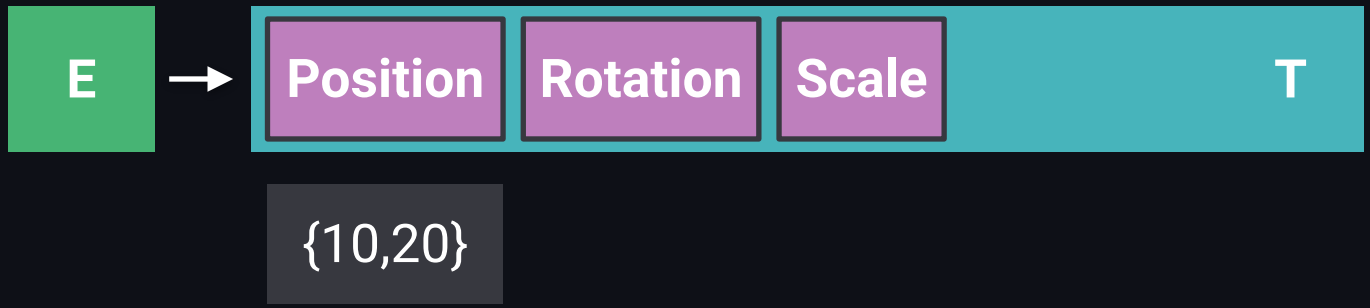


Each component on an entity is associated with a value, which is an instance of the datatype

Flecs Basics

Entities, Types, Components

```
E.set<Position>({10, 20});
```

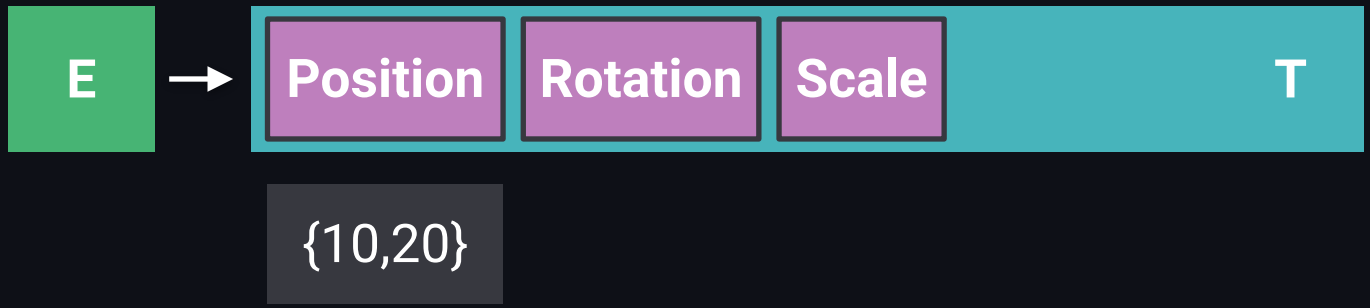


The “set” operation changes a value

Flecs Basics

Entities, Types, Components

```
const Position *p = E.get<Position>();
```



The “get” operation returns a value

Flecs Basics

Entities, Types, Components

```
// Outputs “Position,Rotation,Scale”
std::cout << E.type().str() << std::endl;
```

Types can be inspected and converted to a string.

Flecs Basics

Entities, Types, Components

So far so good?

Flecs Basics

Entities, Types, Components

Let’s get to the fun part

Flecs Basics

Entities, Types, Components

An entity in Flecs is a unique integer (recap)

Flecs Basics

Entities, Types, Components

An entity in Flecs is a unique integer

An *component* in Flecs is also a unique integer

Flecs Basics

Entities, Types, Components

Internally, components are stored as entities

Flecs Basics

Entities, Types, Components

Internally, components are stored as entities

Why is this important?

Flecs Basics

Entities, Types, Components

It means that a *Type* is actually a list of entities

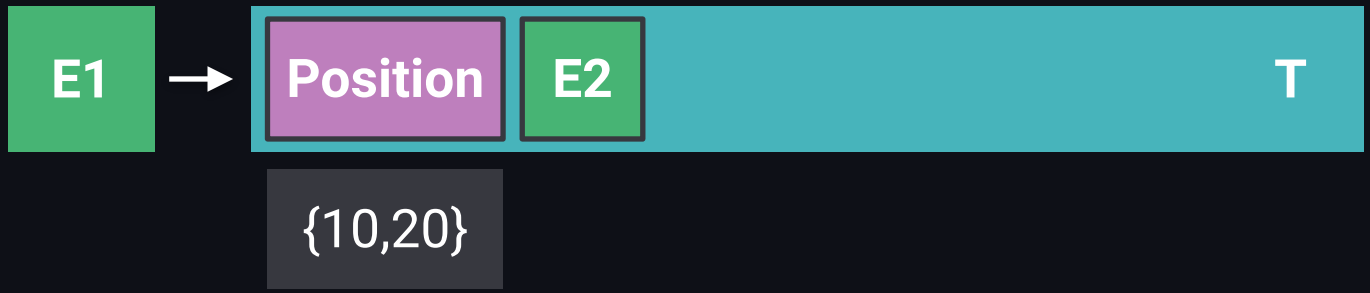
Flecs Basics

Entities, Types, Components

This means that you can add Entities to Entities

Flecs Basics

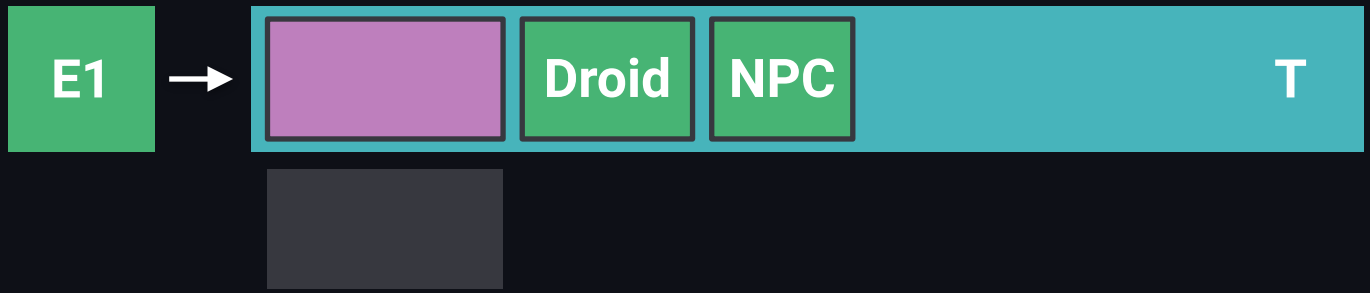
Entities, Types, Components



Not all Entities are Components. A component is associated with a value, a “regular” entity is not.

Flecs Basics

Entities, Types, Components

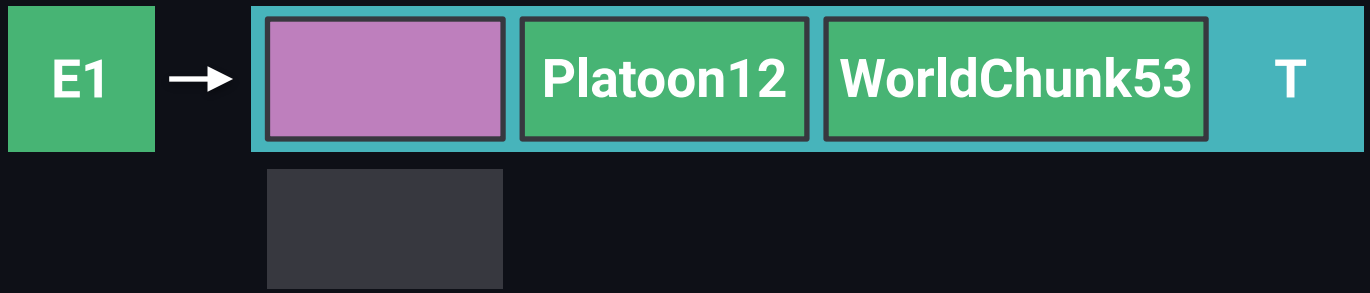


Adding entities is useful for tagging. Tags are useful for subdividing entities, which enables more granular queries.

Flecs Basics

Entities, Types, Components

```
auto Platoon12 = world.entity();
E1.add(Platoon12);
```



Because we use regular entities for tagging, we can create tags at runtime. This is useful when we must filter on runtime generated game “stuff”.

Flecs Basics

Entities, Types, Components

```
struct EmptyType {};
E1.add<EmptyType>();
```

One note: Flecs recognizes empty types, and does not treat them as components but as tags.

Flecs Basics

Entities, Types, Components

Show me code!

Flecs Basics

Entities, Types, Components

So far so good?

Relationships

Relationships are prevalent in games:

A Unit belongs to a Platoon

A Platoon belongs to a Faction

Player1 is an ally of Player2

Relationships in Flecs are a 1st class concept.

This means you can create relationships using the Flecs API.

It also means that you can use ECS queries for relationships, which is much faster than manually iterating & testing a list of entities!

Flecs Basics

Relationships

A Type is a list of entity identifiers (recap)

Flecs Basics

Relationships

~~A Type is a list of entity identifiers (recap)~~

Ok this is not 100% correct

Flecs Basics

Relationships

~~A Type is a list of entity identifiers (recap)~~

Each element in a type is a 64 bit integer

Flecs Basics

Relationships

~~A Type is a list of entity identifiers (recap)~~

Components and tags only take up 32 bits

Flecs Basics

Relationships

This lets us store 2 values per element. This second value can be used to store a relationship kind. This is called a “trait” in Flecs.

Flecs Basics

Relationships

```
auto Dad = world.entity();
auto Mom = world.entity();
auto Bob = world.entity();
auto Alice = world.entity();

E.add_trait(Dad, Bob)
 .add_trait(Mom, Alice);
```

Here's an example of how this can be used to construct a small family tree

Flecs Basics

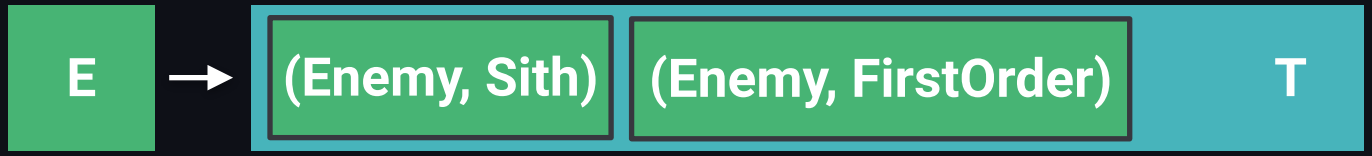
Relationships

```
E.has_trait(Dad, Bob);
```

To test if an entity has a relationship, use the “has_trait” operation.

Flecs Basics

Relationships



Traits can occur multiple times in a Type

Flecs Basics

Relationships

Show me code!

Break! (10 min)

Tip: make sure to **join the Flecs Discord**. It contains a ton of information and users that have built all sorts of games & are excited about ECS :)

Queries

Queries

Queries let an application find all entities that match a certain set of components

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>();
```

When a query is created, you specify the components it subscribes for.

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>();
q.iter(


  [](flecs::iter it, Position *p, const Velocity *v) {

  })
```

An application can then invoke the “iter” function as many times as needed, to get the entities & components that match.

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>();
q.iter(


  [](flecs::iter it, Position *p, const Velocity *v) {

  })
```

ProTip: queries are expensive to create, cheap to evaluate. Cache your queries, don’t re-create them each time you need one!

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>();
q.iter(

  // Outer loop, invoked for each matched Type
  [](flecs::iter it, Position *p, const Velocity *v) {

    // Inner loop, invoked for each entity in the Type
    for (auto i : it) {
      p[i].x += v[i].x; // Contiguous arrays: Happy cache!
      p[i].y += v[i].y;
    }
  })
```

Flecs groups entities by Type. Queries return entities in batches: one batch per matched Type.

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>(“!Speed”);
q.iter(
 // Outer loop, invoked for each matched Type
  [](flecs::iter it, Position *p, const Velocity *v) {
     // ...
  })
```

Components can either be specified as datatypes, or in a query string. The query string has support for more complex features, like operators.

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>();
q.each(
  [](flecs::entity e, Position& p, const Velocity& v) {
    p.x += v.x;
    p.y += v.y;
  })
```

The “each” function lets you iterate a query with less code: it automatically combines the outer and the inner loop.

Flecs Basics

Queries

```
q = world.query<Position, const Velocity>();
q.each(
  [](flecs::entity e, Position& p, const Velocity& v) {
    p.x += v.x;
    p.y += v.y;
  })
```

ProTip: Flecs queries are really fast to evaluate. Use this to your advantage: create smaller systems for more specific sets of entities.

Flecs Basics

Queries

Show me code!

Systems

Systems

A system is a combination of a query and a function. Systems can be automatically ran by Flecs.

Systems are an optional feature. Applications can be built entirely with just queries. This is especially common when integrating Flecs with existing engines.

Flecs Basics

Systems

```
world.system<Position, const Velocity>("Move")
```

Just like a query, you specify a list of components for a system. You can optionally provide a system name, which helps debugging

Flecs Basics

Systems

```
world.system<Position, const Velocity>("Move")
  .kind(flecs::OnUpdate)
```

In addition, you can specify when the system should be ran. By default this is the OnUpdate “phase”.

Flecs Basics

Systems

```
world.system<Position, const Velocity>("Move")
  .kind(flecs::OnUpdate)


// Executed after Move
world.system<const Position, Target>("FindTarget")
  .kind(flecs::OnUpdate)
```

Systems assigned to the same phase are guaranteed to be executed in order of declaration.

Flecs Basics

Systems

```
world.system<Position, const Velocity>("Move")
  .kind(flecs::OnUpdate)
  .each([](flecs::entity e, Position& p, const Velocity& v) {
    p->x += v->x;
    p->y += v->y;
  });
```

The implementation for a system is set with the "each" or "iter" functions.

Flecs Basics

Systems

```
world.system<Position, const Velocity>("Move")
  .kind(flecs::OnUpdate)
  .each([](flecs::entity e, Position& p, const Velocity& v) {
    p->x += v->x;
    p->y += v->y;
  });

world.progress();
```

To run all systems registered with a world, run the world.progress() function.

Modules

Modules

Modules are an optional feature that let you organize and modularize your components and systems.

With proper usage of modules, you can build features in a way that can be easily reused across applications.

Flecs Basics

Modules

```
class MyModule {
  MyModule(flecs::world& world) {
    world.module<MyModule>();

    world.component<Position>();
    world.component<Velocity>();

    world.system<Position, const Velocity>("Move")
      .iter( … );
  }
};
```

A module is defined as a class (in C++) that creates all systems and components it contains in the constructor.

Flecs Basics

Modules

```
world.import<MyModule>();
```

To use a module, an application can simply import it. This will register all systems and components with the world.

Flecs Basics

Modules

```
class MyModule {
  MyModule(flecs::world& world) {
    world.module<MyModule>();

    world.import<YetAnotherModule>();

    // …
  }
};
```

Modules can (and often do) depend on other modules.

Flecs Basics

Modules

```
namespace systems {
class Physics {
  Physics(flecs::world& world) {
    world.module<Physics>();

    world.import<components::Physics>();
  }
};
}
```

ProTip: split modules up in components.* and systems.*. This lets you easily swap feature implementations without changing app code, as components stay the same!

Flecs Basics

Modules

```
world.import<flecs::components::transform>();
world.import<flecs::components::physics>();
world.import<flecs::systems::transform>();
world.import<flecs::systems::sokol>();
world.import<flecs::json>();
world.import<flecs::dash>();
```

Check out github.com/flecs-hub! It contains lots of example modules that show how to create various game systems.

Show me code!

That's all for the Flecs basics.

Congratulations, you now know the fundamentals of Flecs! 🎉

The next part of the presentation is about
quality of life features, such as

Hierarchies, **Prefabs** and **State Machines**.

Short Break! (5 min)

Tip: Check the **flecs-hub organization** on GitHub! It has lots of example code that shows how to build all sorts of systems.

Flecs Advanced

Hierarchies

Hierarchies

Probably the #1 question from ECS users is, *“howto hierarchies”*.

DIY ECS hierarchies are a minefield of a design space, with more things you can do wrong than right :(

Flecs has a builtin, efficient hierarchy implementation that is an especially good fit for scene graphs :)

You can still DIY ofc, at your own risk (or pleasure)

Flecs Advanced

Hierarchies

```
auto SpaceShip = world.entity();

auto Railgun = world.entity()
  .add_childof(SpaceShip);

auto TurretLeft = world.entity()
  .add_childof(SpaceShip);

auto TurretRight = world.entity();
  .add_childof(SpaceShip);
```

Creating hierarchies is simple with the builtin “add_childof” function.

```
Railgun.remove_childof(SpaceShip);
```

Hierarchies are dynamic. A parent can be removed with the remove_childof function.

```
SpaceShip.destruct();
```

Deleting a parent deletes all of its children.

Flecs Advanced

Hierarchies

```
q = world.query<Position>("PARENT:Position");
q.iter(
   [](flecs::iter it, Position *p) {
     // Request parent component from iterator. "2" is the 2nd column
     // of the query signature.
     auto parent_p = it.column<Position>(2);

     for (auto i : it) {
       p[i].x += parent_p->x; // Notice parent_p is a pointer
     }
  });
```

Queries can explicitly request components from parent entities.

Flecs Advanced

Hierarchies

```
q = world.query<Position>("CASCADE:Position");
q.iter(
   [](flecs::iter it, Position *p) {
     auto parent_p = it.column<Position>(2);
     for (auto i : it) {
       if (parent_p.is_set() {
         p[i].x += parent_p->x;
       // If m_parent is not set, this is a root entity
       } else {
         p[i].x += parent_p->x;
       }
     }
  });
```

Scene graphs need to transform top-down. The CASCADE modifier enforces BFS order, without modifying the storage.

Flecs Advanced

Hierarchies

```
q = world.query<Position>("CASCADE:Position");
q.iter(
   [](flecs::iter it, Position *p) {
     auto parent_p = it.column<Position>(2);
     for (auto i : it) {
       if (parent_p.is_set()) {
         p[i].x += parent_p->x;
       // If m_parent is not set, this is a root entity
       } else {
         p[i].x += parent_p->x;
       }
     }
  });
```

Note: Only the query's private table cache is sorted.
Sorting is only done when new tables are created.

Flecs Advanced

Hierarchies

```
q = world.query<Position>("CASCADE:Position");
q.iter(
   [](flecs::iter it, Position *p) {
     auto parent_p = it.column<Position>(2);
     if (parent_p.is_set() {
       for (auto i : it) {
         p[i].x += parent_p->x; // No branching in core loop!
       }
     } else {
       for (auto i : it) {
         p[i].x += parent_p->x;
       }
     }
  });
```

ProTip: put the parent check around the loops. It's a bit more typing, but greatly reduces branching in your code!

Flecs Advanced

Hierarchies

```
auto Rocinante = world.entity(“Rocinante”);

auto Railgun = world.entity(“Railgun”)
  .add_childof(Rocinante);

auto r1 = world.lookup(“Rocinante::Railgun”);

auto r2 = Rocinante.lookup(“Railgun”);
```

Entities can be given names. Hierarchies allow you to lookup entities with scoped identifiers.

Flecs Advanced

Hierarchies

Show me code!

Prefabs

Prefabs

When creating entities, it comes in handy if you can create them from a template. Flecs has a builtin prefab feature that makes this easy (and efficient!) to do.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});
```

Prefabs are like regular entities, but are created with the “prefab” method. This ensures that prefabs are not matched with systems.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});

auto Rocinante = world.entity()
  .add_instanceof(Frigate);
```

To instantiate a prefab, use the “add_instanceof” function.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});

auto Rocinante = world.entity()
  .add_instanceof(Frigate);

// This pointer points to the component of Frigate!
const MaxSpeed *ms = Rocinante.get<MaxSpeed>();
```

add_instanceof causes components to be shared between the prefab and instance. Shared components are stored once in memory.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});

auto Rocinante = world.entity()
  .add_instanceof(Frigate);

// This pointer points to the component of Frigate!
const MaxSpeed *ms = Rocinante.get<MaxSpeed>();
```

ProTip: if you have lots of redundant data across entities, use instancing instead. This reduces memory footprint & improves cache perf.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});

auto Rocinante = world.entity()
  .add_instanceof(Frigate)
  .add<MaxSpeed>(); // Overrides MaxSpeed, copy value from Frigate
```

Components can be overridden, which adds them to the instance.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});

auto Rocinante = world.entity()
  .add_instanceof(Frigate)
  .add<MaxSpeed>();

Rocinante.remove<MaxSpeed>(); // Re-exposes MaxSpeed from the base
```

When an override is removed, the base component will be re-exposed.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2})
  .add_owned<MaxSpeed>();

auto Rocinante = world.entity()
  .add_instanceof(Frigate);

// Rocinante now has an override of MaxSpeed with value {100}
```

Prefab components can be auto-overridden with the add_owned() function. This is ensures instances get an initialized, private copy.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2})
  .add_owned<MaxSpeed>()
  .add_owned<Attack>()
  .add_owned<Defense>();

auto Rocinante = world.entity()
  .add_instanceof(Frigate);
```

ProTip: using prefabs in combination with automatic overriding is an easy and fast way to initialize component data for new entities!

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});
  .add_owned<MaxSpeed>();

auto FastFrigate = world.prefab(“FastFrigate”)
  .add_instanceof(Frigate)
  .set<MaxSpeed>({200});
```

Prefabs can instantiate each other. This enables specialization of prefabs, and makes it easier to write DRY templates.

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2})
  .add_owned<MaxSpeed>();

auto FastFrigate = world.prefab(“FastFrigate”)
  .add_instanceof(Frigate)
  .add_instanceof(SportsCarMaterial)
  .set<MaxSpeed>({200});
```

Multiple prefabs can be added at the same time

Flecs Advanced

Prefabs

```
auto Frigate = world.prefab(“Frigate”)
  .set<MaxSpeed>({100})
  .set<Attack>({5})
  .set<Defense>({2});

auto RailGun = world.prefab(“RailGun”)
  .add_childof(Frigate);

auto Rocinante = world.entity()
  .add_instanceof(Frigate);

auto r = Rocinante.lookup(“RailGun”);
```

Children of a prefab are automatically copied to the instance.

Flecs Advanced

Prefabs

```
q = world.query<Velocity>("SHARED:MaxSpeed");

q.iter(
   [](flecs::iter it, Velocity *v) {
     auto max_speed = it.column<MaxSpeed>(2);

     for (auto i : it) {
       // Notice max_speed is a pointer
       if (v[i].x > max_speed->value) v.x = max_speed->value;
     }
  });
```

By default shared components are not matched by systems. To match a shared component, use the SHARED modifier.

Flecs Advanced

Prefabs

```
q = world.query<Velocity>("ANY:MaxSpeed");

q.iter(
   [](flecs::iter it, Velocity *v) {
     auto max_speed = it.column<MaxSpeed>(2);
     for (auto i : it) {
       if (!max_speed.is_shared()) {
         if (v[i].x > max_speed[i].value) v.x = max_speed[i].value;
       } else {
         // Notice max_speed is a pointer
         if (v[i].x > max_speed->value) v.x = max_speed->value;
       }
     }
  });
```

With the ANY modifier a system matches both SHARED and OWNED components.

Flecs Advanced

Prefabs

Show me code!

State Machines

State Machines

State machines are common, but can be difficult to model in ECS.

Transitioning to a new state (tag) requires knowing the previous state (tag) to remove it. Plain tags don’t make this easy.

Flecs has a builtin feature that lets you model mutually exclusive tags, which come in handy when storing state machines.

Flecs Advanced

State Machines

```
auto Walking = world.entity(“Walking");
auto Running = world.entity("Running");
auto Movement = world.type(“Movement",
        "Walking, Running");

auto e = world.entity()
  .add_switch(Movement)
  .add_case(Walking);

e.add_case(Running); // Removes Walking
```

A “switch” models a set of mutually exclusive tags (“cases”). Adding one case will remove the previous case that belongs to that switch.

Flecs Advanced

State Machines

```
q = world.query<>("CASE|Walking");

q.iter([](flecs::iter it) {
  for (auto i : it) {
    cout << it.entities(i).name() << " is Walking!" << std::endl;
  }
});
```

Queries can request all entities with a specific case.

Flecs Advanced

State Machines

```
q = world.query<>("SWITCH|Movement");

q.iter([](flecs::iter it) {
  // States are stored in an array with raw entity ids
  auto states = it.column<flecs::entity_t>(1);

  for (auto i : it) {
    // Wrap state in entity class
    auto state = it.world.entity(states[i]);
    cout << it.entities(i).name()
         << " is " << state.name() << std::endl;
  }
});
```

Queries can also request all cases for a specific switch

Show me code!

Singletons

Singletons

Games often have components of which there is only a single instance. Flecs has an API for storing and retrieving singleton components.

Flecs Advanced

Singletons

```
// Set Game singleton
world.set<Game>({ 10, 20, 30 });

// Get Game singleton
const Game *g = world.get<Game>();
```

Singletons are set & get with methods on the world object.

Flecs Advanced

Singletons

```
world.set<Game>({ 10, 20, 30 });


const Game *g = world.get<Game>();

// Return singleton entity for Game
auto s_game = world.singleton<Game>();

// true!
s_game == world.component<Game>();
```

A singleton value is stored on the component entity.

Flecs Advanced

Singletons

```
q = world.query<Position>(“$Game”);

q.iter([](flecs::iter it, Position *p) {
  auto game = it.column<Game>(2);
  for (auto i : it) {
    if (p[i].x > game->max_x) p[i].x = game->max_x;
  }
});
```

Queries can request singletons with the $ character.

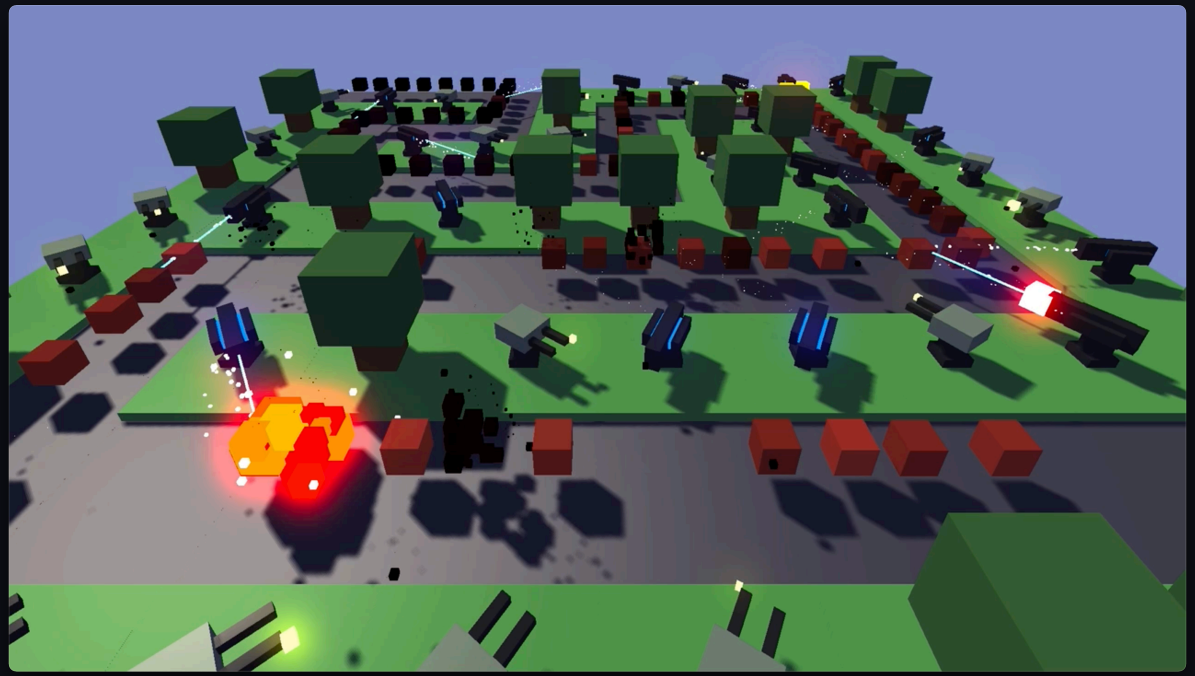
Flecs Advanced

Singletons

Show me code!

Flecs Advanced

Tower Defense Example



Small “pure” ECS demo that shows how to use modules, prefabs, systems and a lot more.

Still under construction!

https://github.com/SanderMertens/tower_defense

That’s it!

Thanks for attending 🎉

Github: https://github.com/SanderMertens/flecs
Discord: https://discord.gg/BEzP5Rgrrp