



# Insomniac Physics

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# Overview

- Go over the evolution of IG physics system
- Shaders
- Library Shaders
- Custom event shaders

# Original Design

## Resistance: Fall of Man

- Ported From PC to PS3
- PPU Heavy
- SPU Processes Blocked
- Two Jobs (Collision, Simulation)
- Simulation Jobs too memory heavy dispatched to PPU version.
- Expensive

# Original Design Resistance: Fall of Man

Physics Update



Gather Potentially  
Colliding Objects

# Original Design Resistance: Fall of Man

Physics Update



Cache Collision  
Geometry

# Original Design Resistance: Fall of Man

Physics Update



Run  
SPU Collision Jobs

# Original Design

## Resistance: Fall of Man

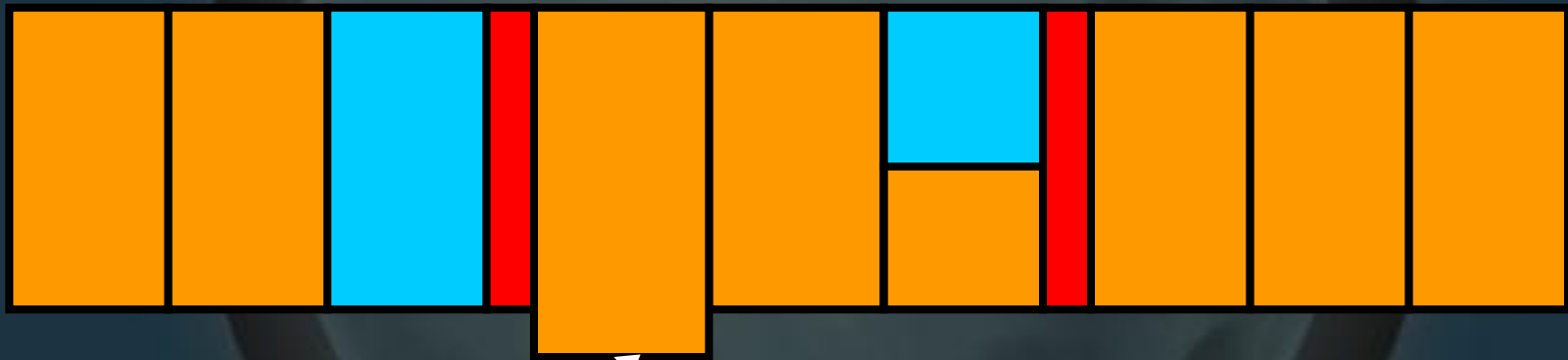
Physics Update



Sync

# Original Design Resistance: Fall of Man

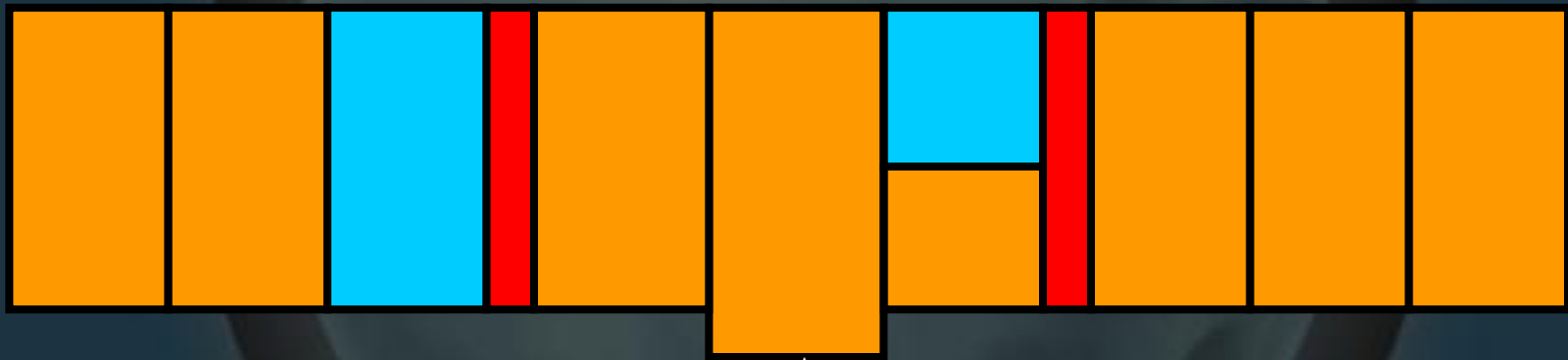
Physics Update



Process Contact  
Constraints

# Original Design Resistance: Fall of Man

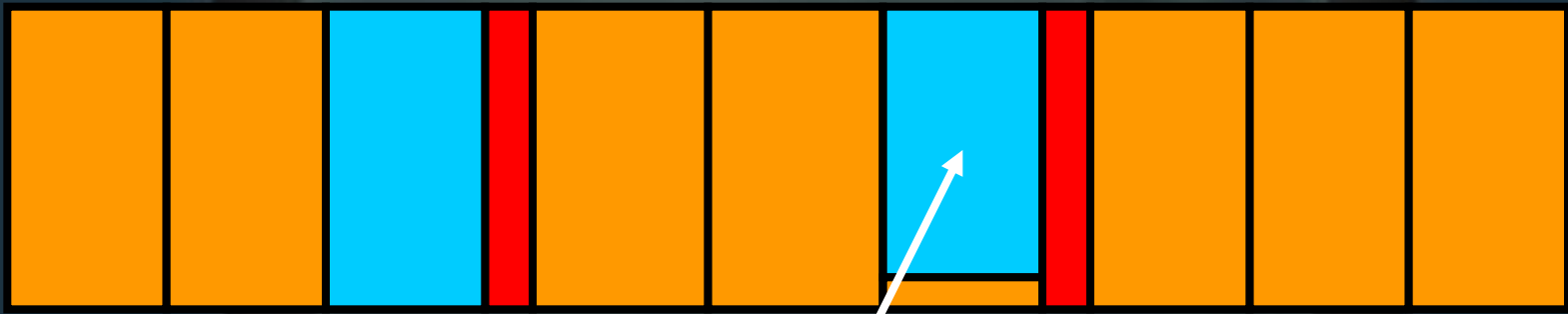
Physics Update



Create Simulation  
Pools

# Original Design Resistance: Fall of Man

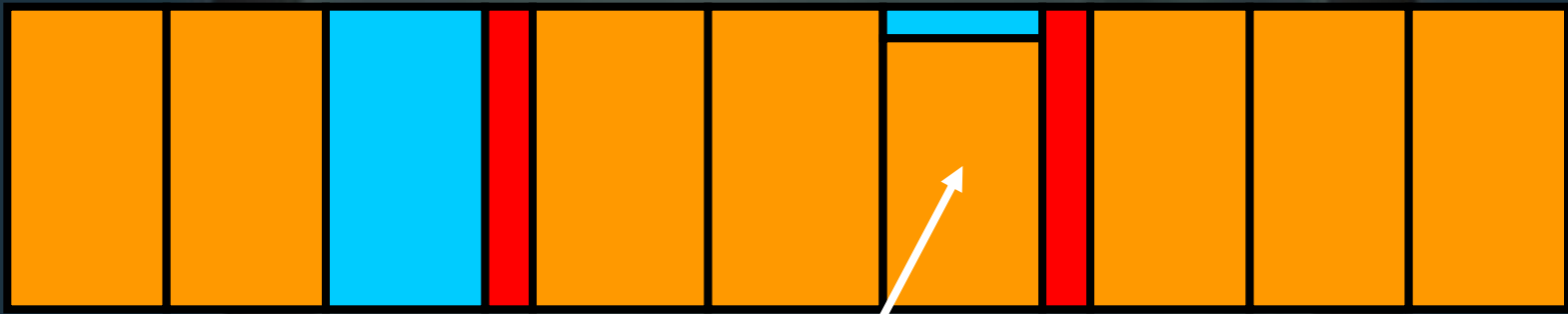
Physics Update



Run  
SPU Simulation Jobs

# Original Design Resistance: Fall of Man

Physics Update



Run Simulations  
Too Big For SPU!

# Original Design

## Resistance: Fall of Man

Physics Update



Sync

# Original Design Resistance: Fall of Man

Physics Update



Process Results

# Original Design

## Resistance: Fall of Man

Physics Update



Call Events

# Original Design

## Resistance: Fall of Man

Physics Update



Update Joints

# Original Design

## Resistance: Fall of Man

- Simulation Jobs Ran as Pools were generated.
- PPU Simulation Jobs ran concurrently with the SPU Simulation Jobs
- This was the **ONLY** asynchronous benefit!
- Not much!

# Original Design Resistance: Fall of Man

- Physics had the largest impact on frame rate
- Pipeline design made it difficult to reliably optimize
- There was A LOT to learn

# Phase 2

## Ratchet & Clank Future

- Collision and Simulation run in a single SPU Job
- Single sync-point
- Large PPU window from start of Job to End of Job
- Use of Physics Shaders

# Phase 2

## Ratchet & Clank Future

Physics Update



Gather Potentially Colliding Objects

# Phase 2

## Ratchet & Clank Future

Physics Update



Cache Collision Geometry

# Phase 2

## Ratchet & Clank Future

Physics Update



Start Physics SPU Jobs

# Phase 2

## Ratchet & Clank Future

Physics Update



Do Collision

# Phase 2

## Ratchet & Clank Future

Physics Update



Generate Simulation Pools

# Phase 2

## Ratchet & Clank Future

Physics Update



Simulate

# Phase 2

## Ratchet & Clank Future

Physics Update



Update Joints

# Phase 2

## Ratchet & Clank Future

Physics Update



DMA Results

# Phase 2

## Ratchet & Clank Future

Physics Update



Sync

# Phase 2

## Ratchet & Clank Future

Physics Update



Update Events

# Phase 2

## Ratchet & Clank Future

- Shaders helped free up local store
- Each big component had it's own set of shaders
- Constraints
- Solvers
- User customized data transformation

# Physics Intersection Shaders

## Example Function Prototype

```
unsigned int SphereOBB(const CollPrim &a, const CollPrim &b, CollResult *results)
```

- Shaders are loaded into local store during the collision process and called via a function table using a mask created by geometry ID
- Rollback local store when done
- Savings of up to 70k of local store usage

# Physics Jacobian Shaders

## Example Function Prototype

```
unsigned int BuildJDBall(Constraint *c, Manifold *m, RigidBody *rblist, float fps,  
                        float error, float dscale, Jacobian *jlist,  
                        CommonTrig *trig_funcs, CommonFunc *common_funcs,  
                        ConstraintFunc *constraint_util);
```

- An example of a shader being called from another shader
- Constraints are sorted by type, then the corresponding shader is loaded to process a group of like constraints
- Saves us roughly 100k!
- We can add more constraint types without worrying about impact on kernel size

# Physics Jacobian Shaders

## Example Function Prototype

```
unsigned int BuildJDBall(Constraint *c, Manifold *m, RigidBody *rblist, float fps,  
                        float error, float dscale, Jacobian *jlist,  
                        CommonTrig *trig_funcs, CommonFunc *common_funcs,  
                        ConstraintFunc *constraint_util);
```

- CommonTrig contains pointers to trigonometry functions that live in the main physics kernel
- Sin, Cos, ACos, Atan, etc...
- Any optimizations will benefit the shaders without having to re-build them

# Physics Jacobian Shaders

## Example Function Prototype

```
unsigned int BuildJDBall(Constraint *c, Manifold *m, RigidBody *rblast, float fps,  
                        float error, float dscale, Jacobian *jlist,  
                        CommonTrig *trig_funcs, CommonFunc *common_funcs,  
                        ConstraintFunc *constraint_util);
```

- CommonFunc contains pointers to standard functions stored in the physics kernel
- Printf, Dma(get,put), etc...

# Physics Jacobian Shaders

## Example Function Prototype

```
unsigned int BuildJDBall(Constraint *c, Manifold *m, RigidBody *rblist, float fps,  
                        float error, float dscale, Jacobian *jlist,  
                        CommonTrig *trig_funcs, CommonFunc *common_funcs,  
                        ConstraintFunc *constraint_util);
```

- ConstraintFunc contains pointers to constraint utility functions that live in the physics kernel
- Generating test vectors for limits
- Constraint smoothing
- Shared between all constraints that have limits so optimization is a great benefit

# Physics Solver Shaders

## Example Function Prototype

```
void SolverSim(SimPool *sim_pool, Manifold *m, char *dimensions, int *jd_build_ea,  
              int *jd_build_size, ManagedLS *allocator, CommonFunc *common_funcs,  
              CommonTrig *trig_funcs, ConstraintFunc *constraint_util);
```

- One of many solver shaders that get loaded by the main physics kernel
- Full Simulation, IK, or “cheap” objects
- `jd_build_ea/size` tells us about our Jacobian functions (where they live / size)
- Local store allocator provided for scratch

# Custom Event Shaders

- Anyone can author their own custom event shader for physics
- Currently we have two custom event shaders.
- The physics kernel passes common functions and a list of DMA tags

# Custom Event Shaders

- Work memory is passed from to kernel to accommodate any temporary data. Currently this is 2k
- Shader author can DMA new data to a PPU buffer of choice

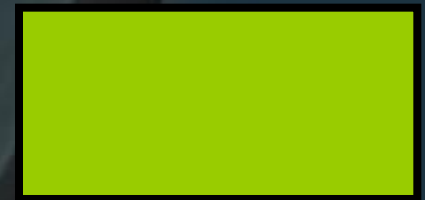
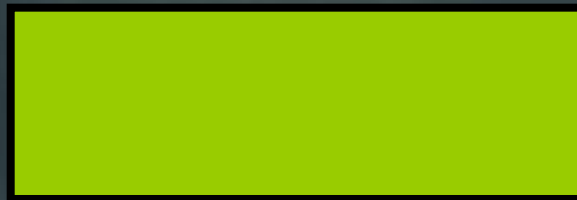
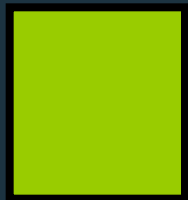
# Phase 3

## Resistance 2

- Immediate and Deferred Modes
- Constraint Data Streaming
- Using library shaders for collision

# Phase 3 Resistance 2

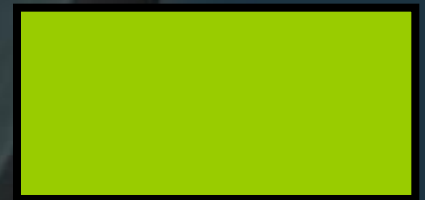
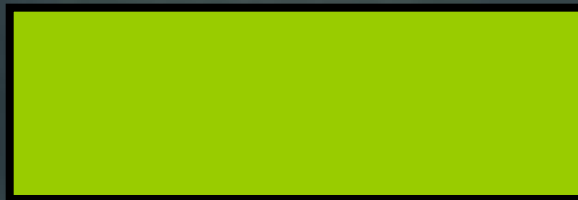
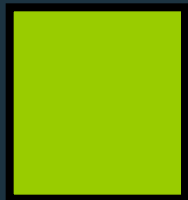
Physics Update



Create Entity (moby) Lists  
Cache Collision Geometry  
[Immediate Jobs]

# Phase 3 Resistance 2

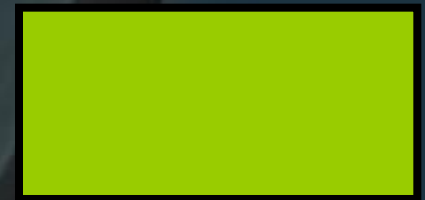
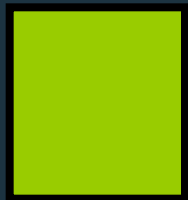
Physics Update



Start Immediate Jobs

# Phase 3 Resistance 2

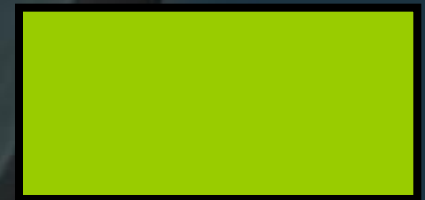
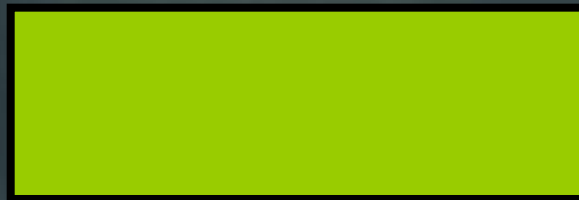
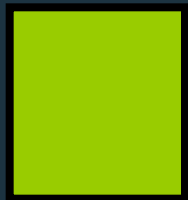
Physics Update



Update Immediate Physics Jobs

# Phase 3 Resistance 2

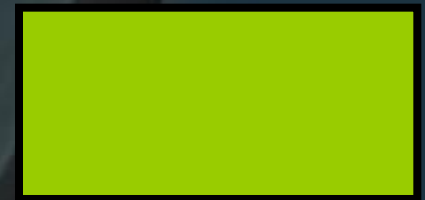
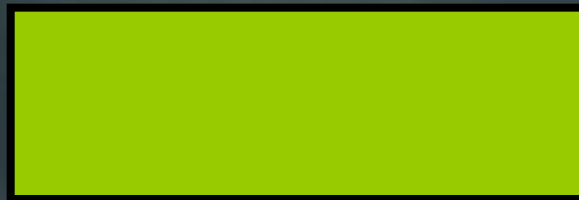
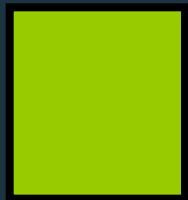
Physics Update



Sync Immediate Physics Jobs

# Phase 3 Resistance 2

Physics Update



Call Events [immediate]

# Phase 3 Resistance 2

Physics Update



Create Entity (moby) Lists  
Cache Collision Geometry  
[Deferred Jobs]

# Phase 3 Resistance 2

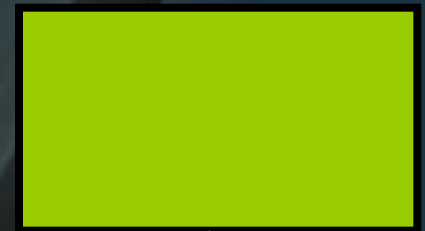
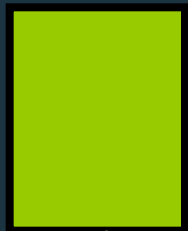
Physics Update



Start Deferred Physics Jobs

# Phase 3 Resistance 2

Physics Update

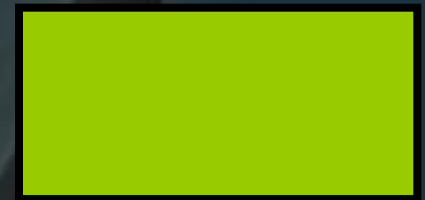
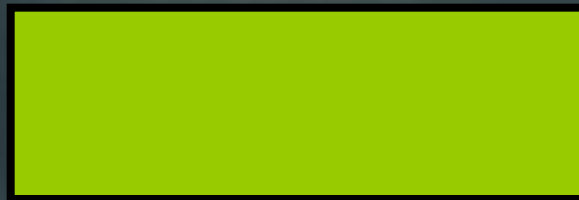
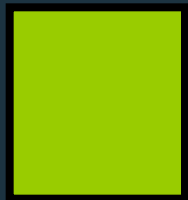


Update Deferred Jobs



# Phase 3 Resistance 2

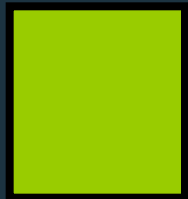
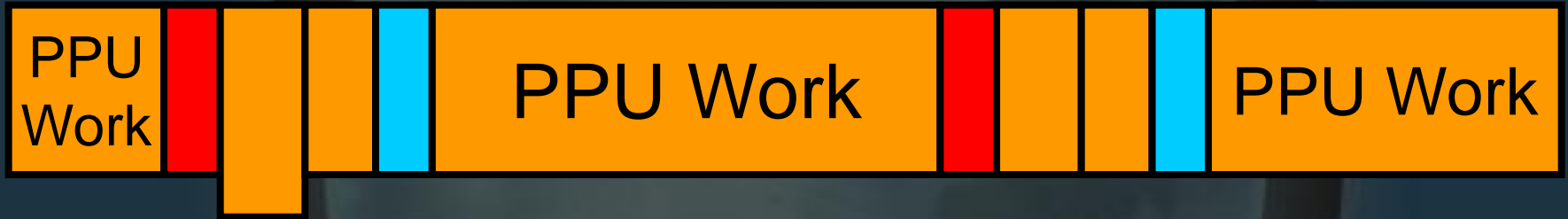
Physics Update



Sync Deferred Physics Jobs

# Phase 3 Resistance 2

Physics Update



Call Events [deferred]

# Immediate and Deferred Modes

- Physics objects that had no other gameplay or animation based dependencies didn't need to finish in one frame
- Ragdolls had a one frame immediate update and then defaulted to deferred so they could reflect one frame of simulation without "popping"

# Immediate and Deferred Modes

- IK is run in immediate mode because it is being constantly being tweaked by gameplay. Lag is not an option
- Having a deferred process improved our frame rate immensely since the majority of the high volume environments had “fire-and-forget” physics objects

# Constraint Data Streaming

- Even with shaders, solver could run out of local store
- Changed the solver update so that only 8 chunks of constraint data were allocated
- Solver chews on data while DMAing next list of constraints

# Collision Shader Library

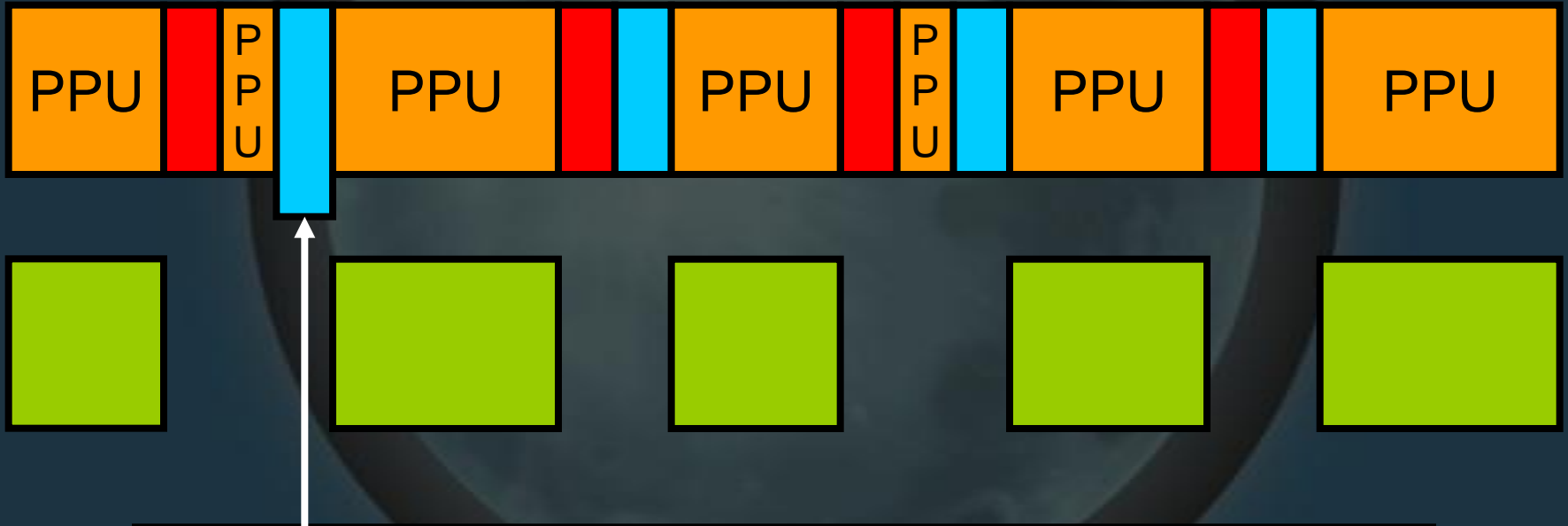
- Having multiple versions of the same type of thing adds more work and you have to optimize more than once.
- Not practical
- Physics native collision routines made available to all
- Great re-use and optimization benefit
- Resistance 2 successfully shipped with this model in place

# Current Phase

- Building of physics object lists as an SPU job
- Atomic allocation of PPU memory for heavily used data types as well as physics scratch memory
- Use of library shaders for broad phase collision caching

# Current Phase

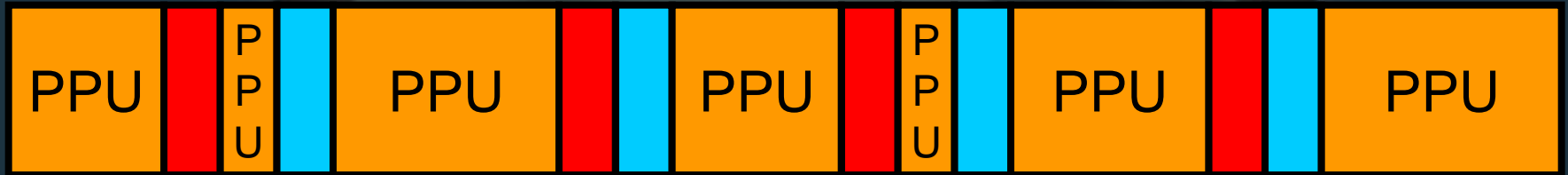
Physics Update



Start Entity Gathering & Collision Caching  
SPU Job [for immediate jobs]

# Current Phase

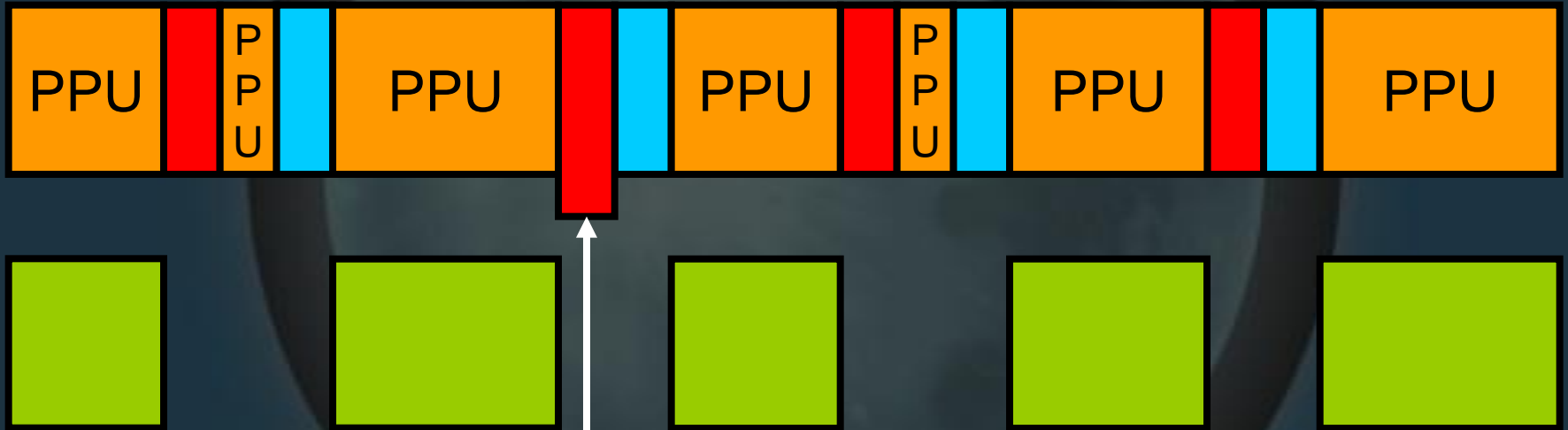
Physics Update



Gather Entities  
Cache Collision, Pre-culling

# Current Phase

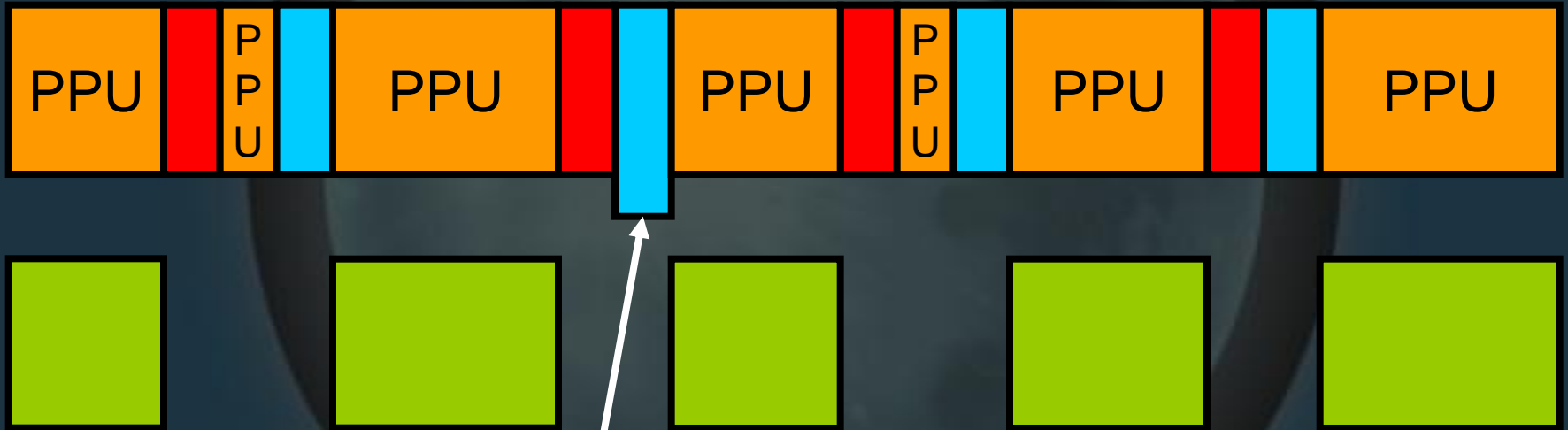
Physics Update



Sync Gathering Jobs [for immediate]

# Current Phase

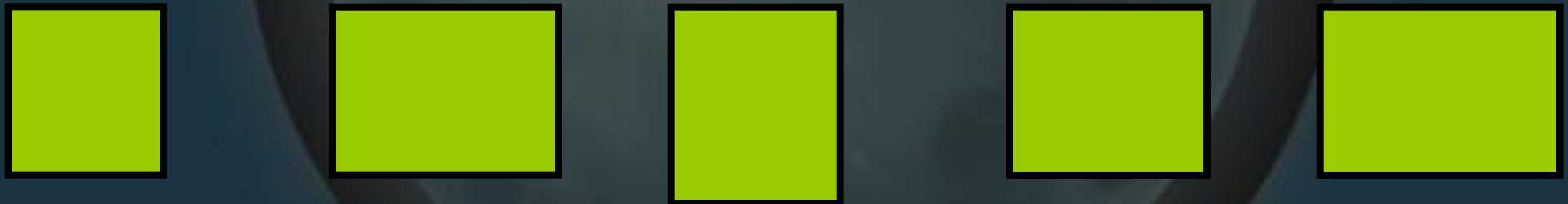
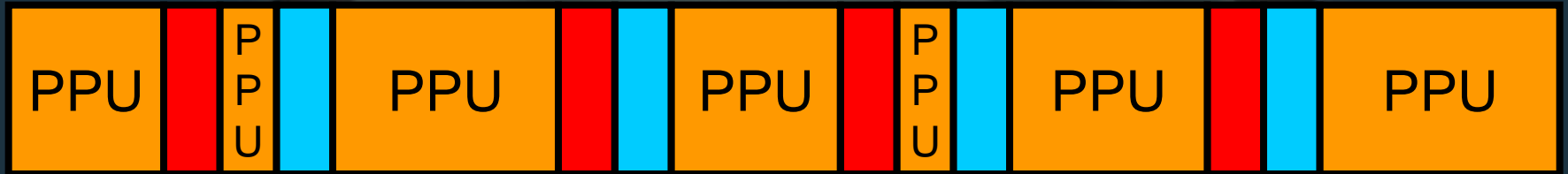
Physics Update



Start Immediate Physics Jobs

# Current Phase

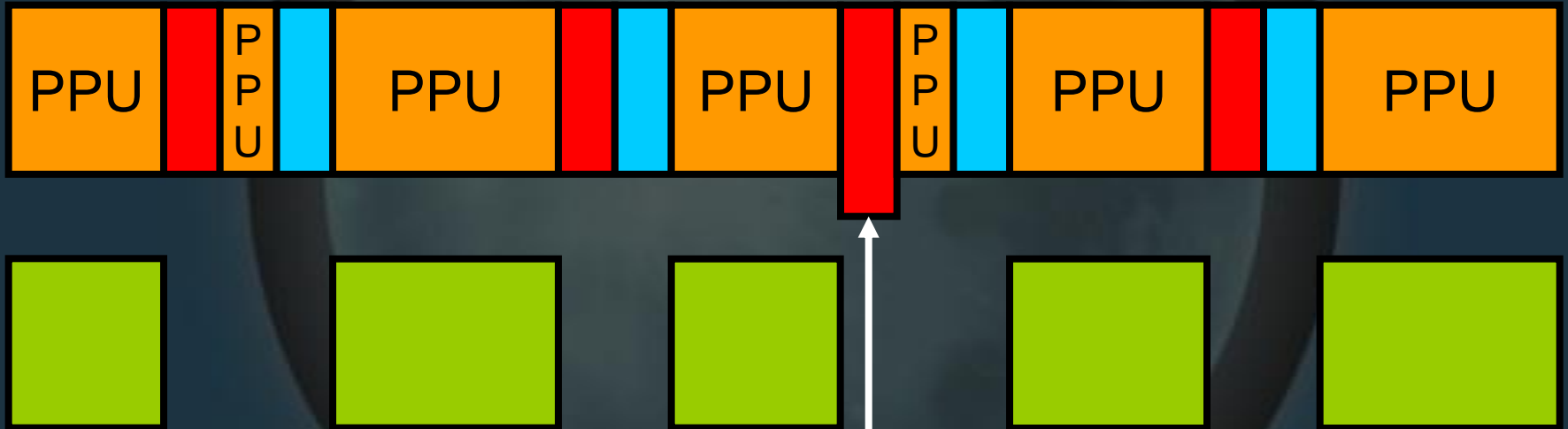
Physics Update



Update Immediate Physics Jobs

# Current Phase

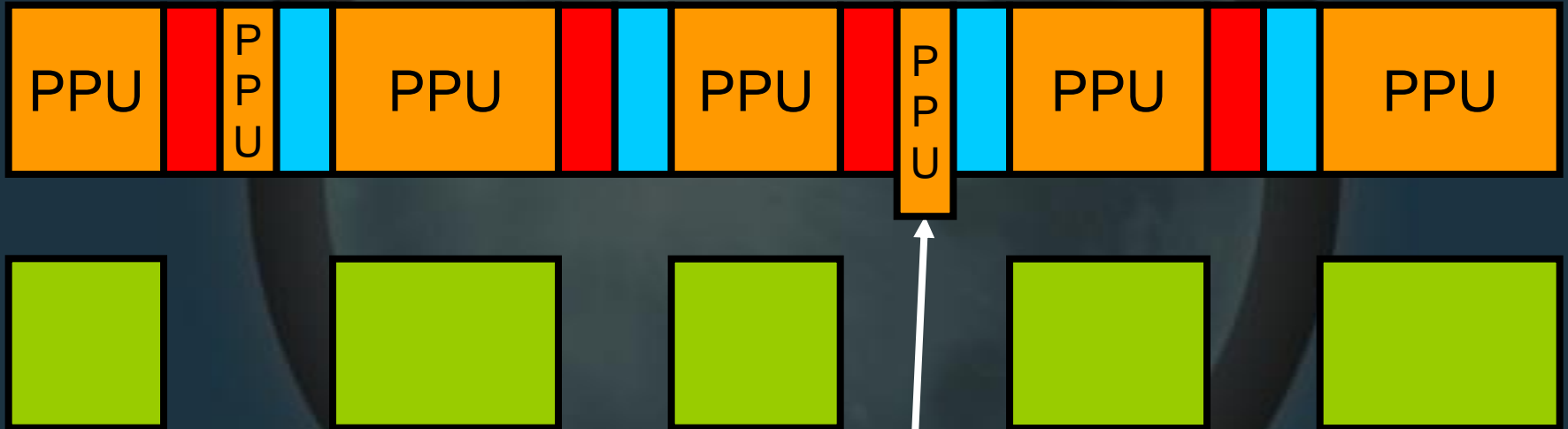
Physics Update



Sync Immediate Jobs

# Current Phase

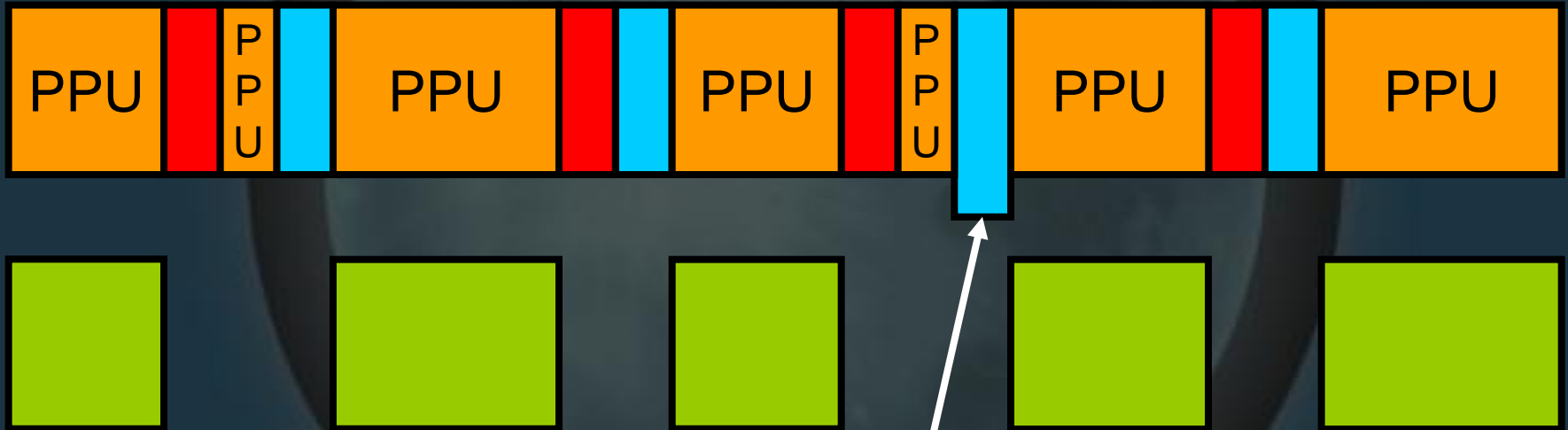
Physics Update



Call Events [immediate]

# Current Phase

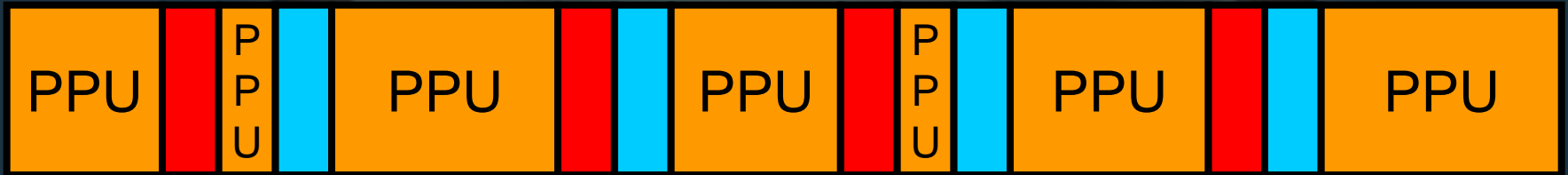
Physics Update



Start Entity Gathering & Collision Caching  
SPU Job [for deferred jobs]

# Current Phase

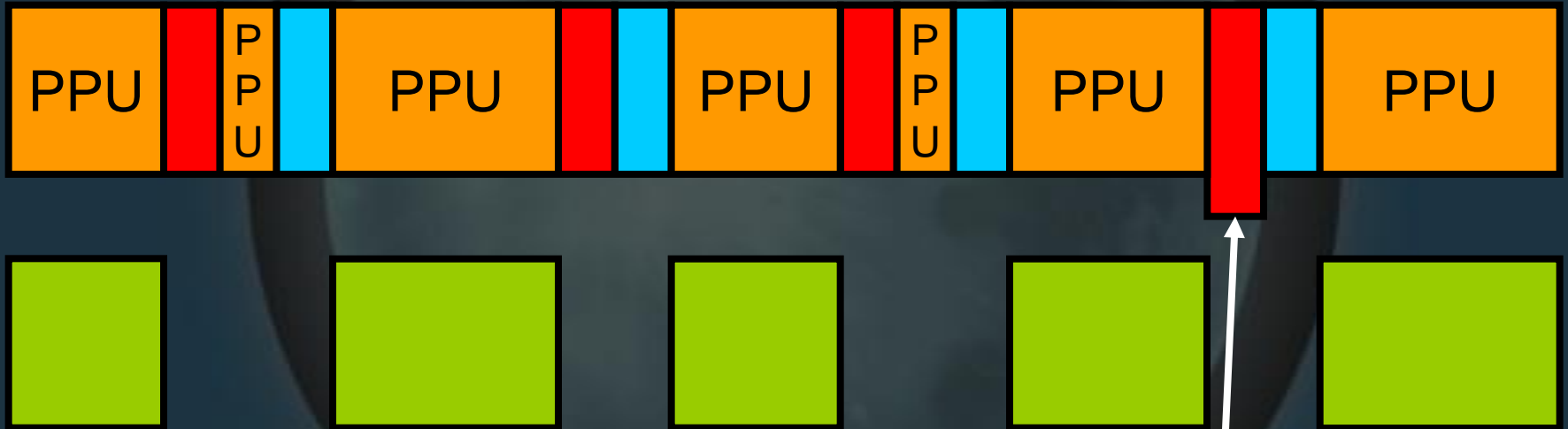
Physics Update



Gather Entities  
Cache Collision, Pre-culling

# Current Phase

Physics Update



Sync Gathering Jobs [for deferred]

# Current Phase

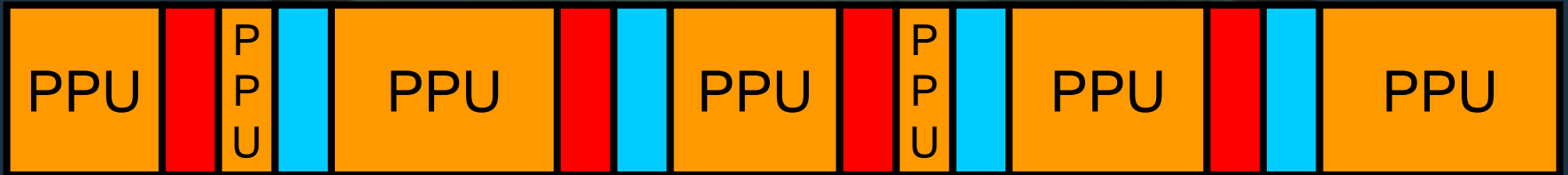
Physics Update



Start Deferred Jobs

# Current Phase

Physics Update



Update Deferred Jobs



# Current Phase

Physics Update



Sync Deferred Jobs

# Current Phase

Physics Update



Call Events [deferred]

# Building Object Lists

- Object list building was taking up valuable time
- Caching geometry was a blocked process on the PPU
- Very expensive
- Now all object lists and geometry caches are generated on the SPU

# Building Object Lists

- Larger physics data types organized for streaming
- Generating object lists requires allocation of data structures from the PPU
- This includes allocating scratch space for joint re-ordering and packed rigid body data

# Atomic Allocation

- Converted PPU fixed block allocations to atomic allocations
- Physics scratch buffer allocation had to be atomic as well
- Rather straight-forward but...
- Exposed a lot of pre-existing problems with the way data was allocated on the PPU


# Broad Phase Collision Shaders

- Previously, was only possible to gather game collision geometry on the PPU
- Insomniac Collision System ran on its own SPU
- Now the functions are in a shader library
- We can build physics collision data on the SPU through the use of the shader library interface
- Saved valuable time!

# Looking Forward



- Optimize DMAs
- Better data organization
- Convert more of the physics kernel into Shaders
- Find more opportunities for interleaving SPU update with PPU



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