Purely Functional 3D in Typed Racket

or

Spoon-Feeding For the Functional Purist

Neil Toronto

RacketCon 2014

3D Engines

- High-level abstraction layer (usually a library) between program and GPU

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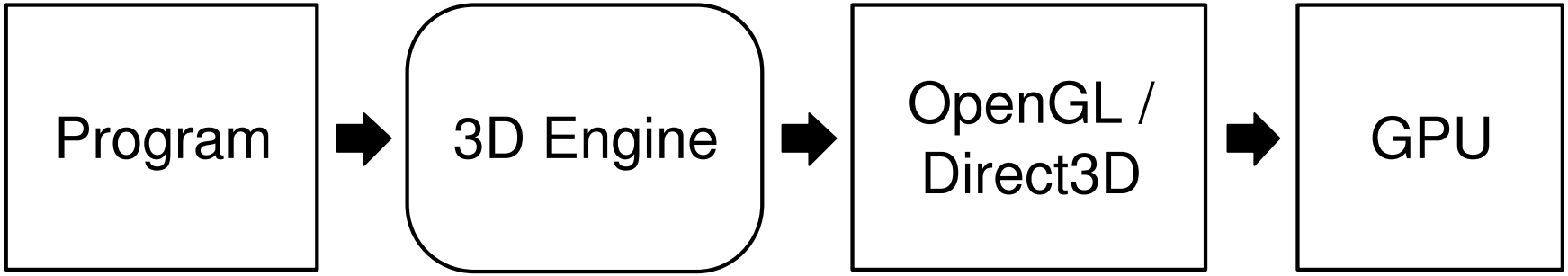

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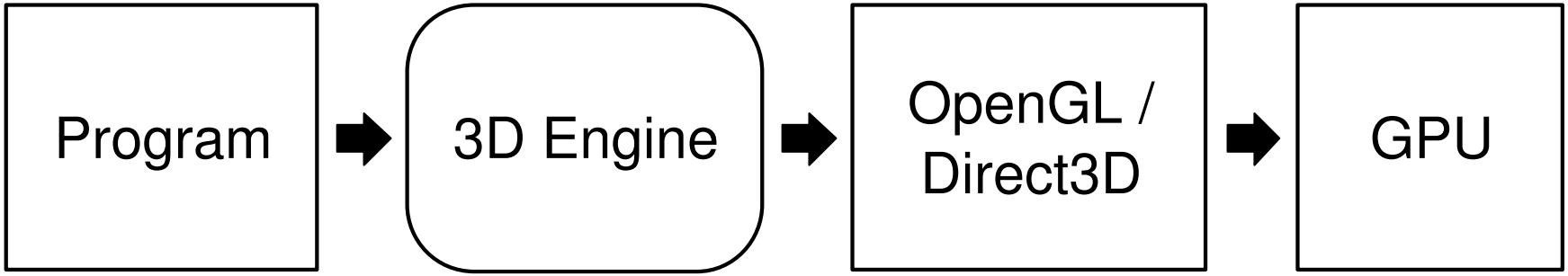

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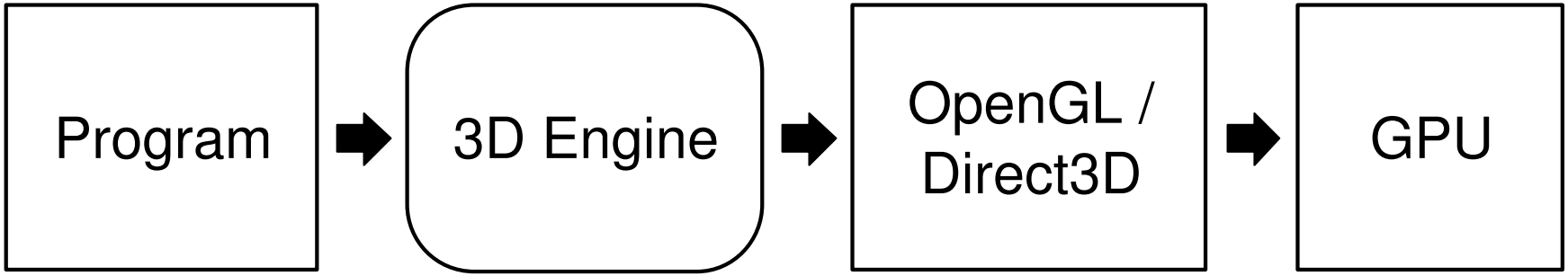
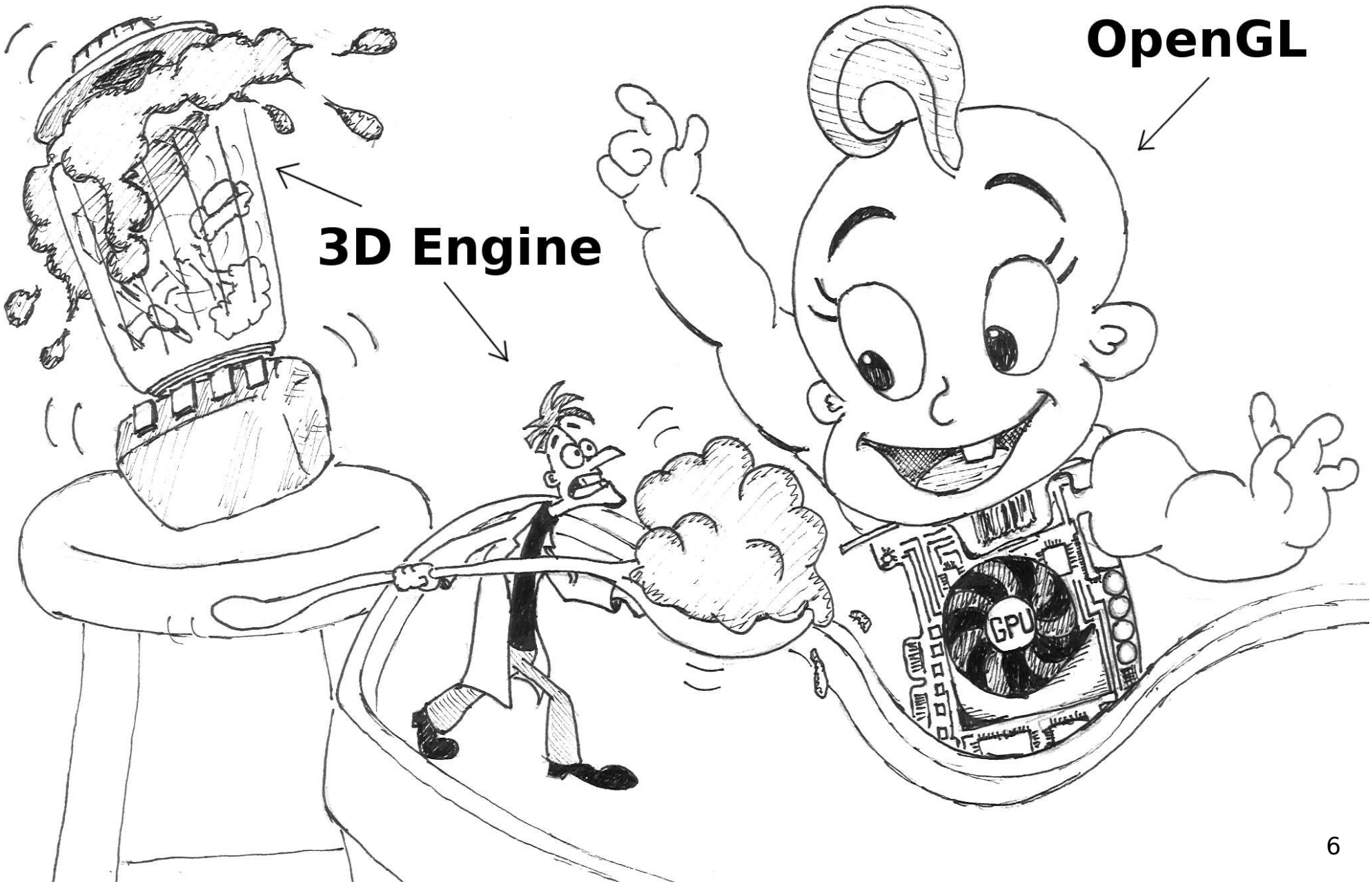


- Examples: Unity, Unreal, Rage (rendering parts)
- Problem: All are built around mutation

What Does a 3D Engine Do?



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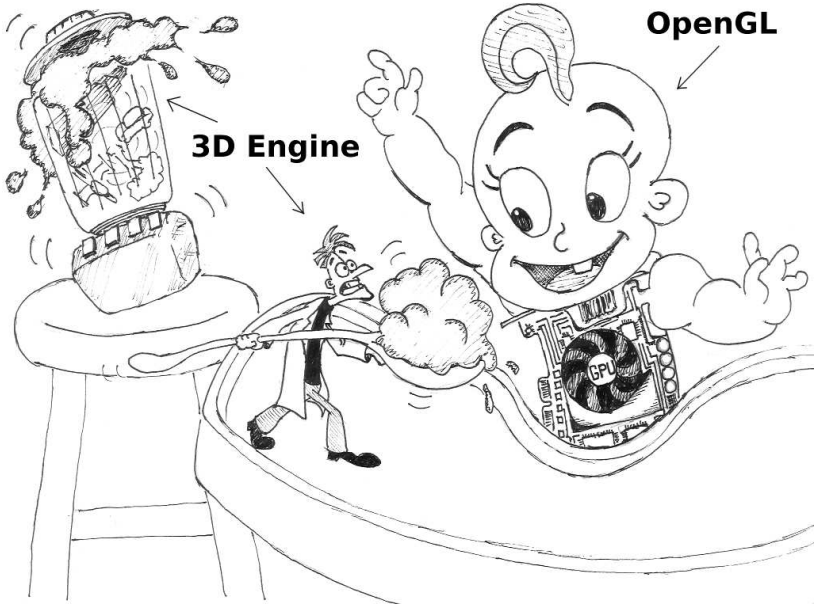

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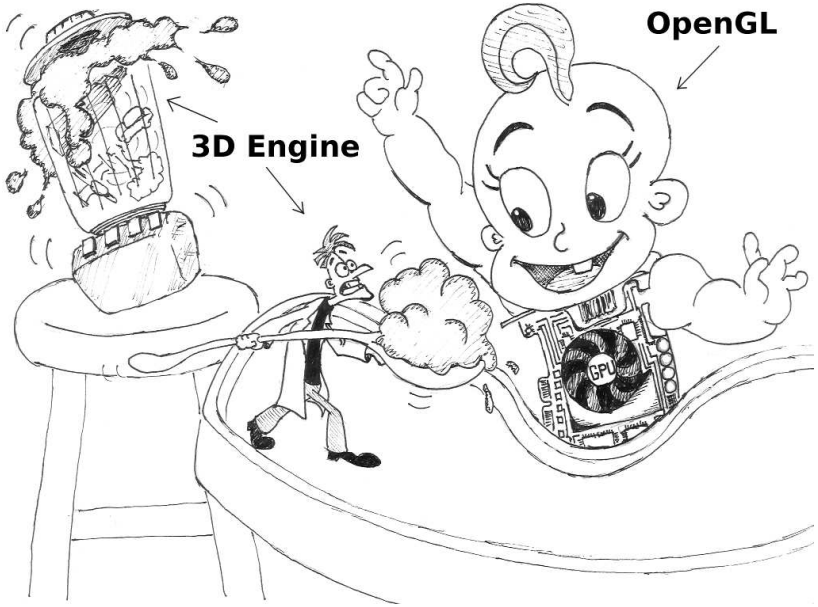

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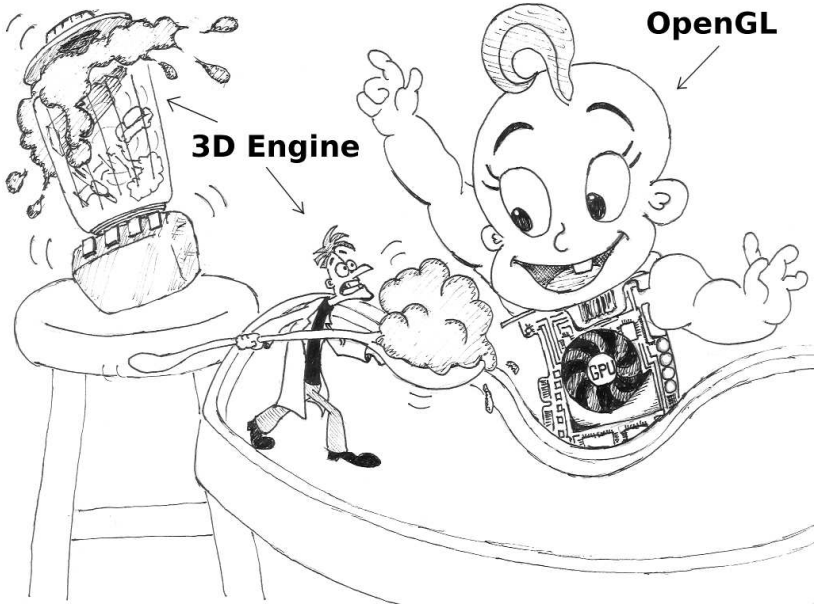

- Giant baby consumes homogenous, bland, first-order vertex data
- Giant baby often must be tricked
- Giant baby is very hungry but can swallow only a few hundred spoonfuls per frame

Imperative Engine API

Commands

```
(add-shape! ...)
(move-shape! ...)
(add-light! ...)
(draw-scene!)
```

3D Engine

Scene Database

Algorithms

High-Powered Blender

Scene Databases

Scene database: a data structure that makes *spatial* queries (e.g. point-inside) efficient

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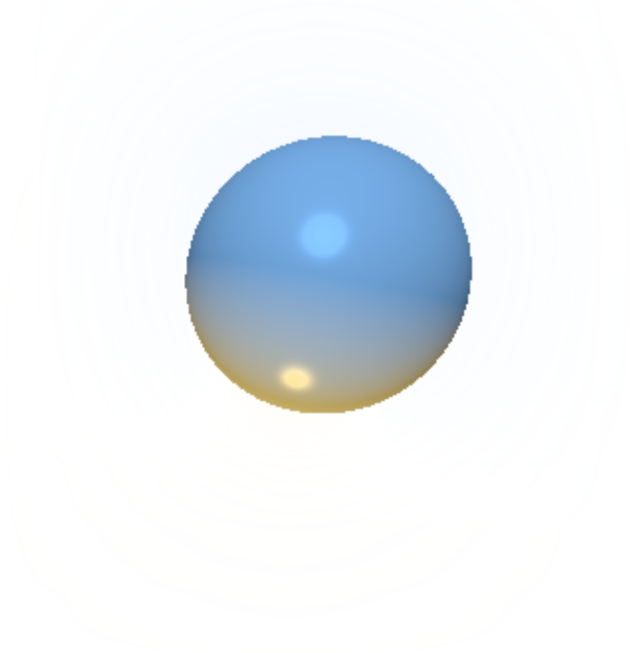

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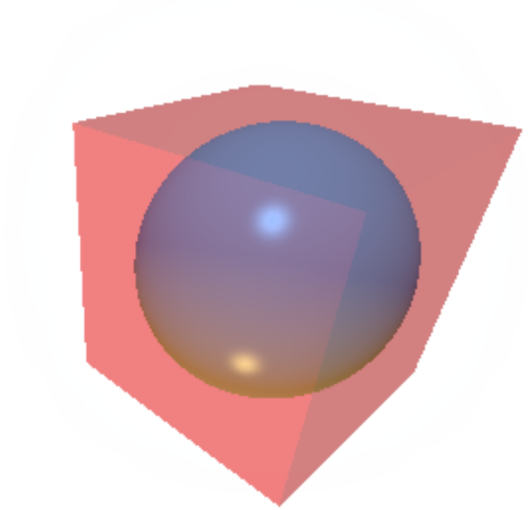

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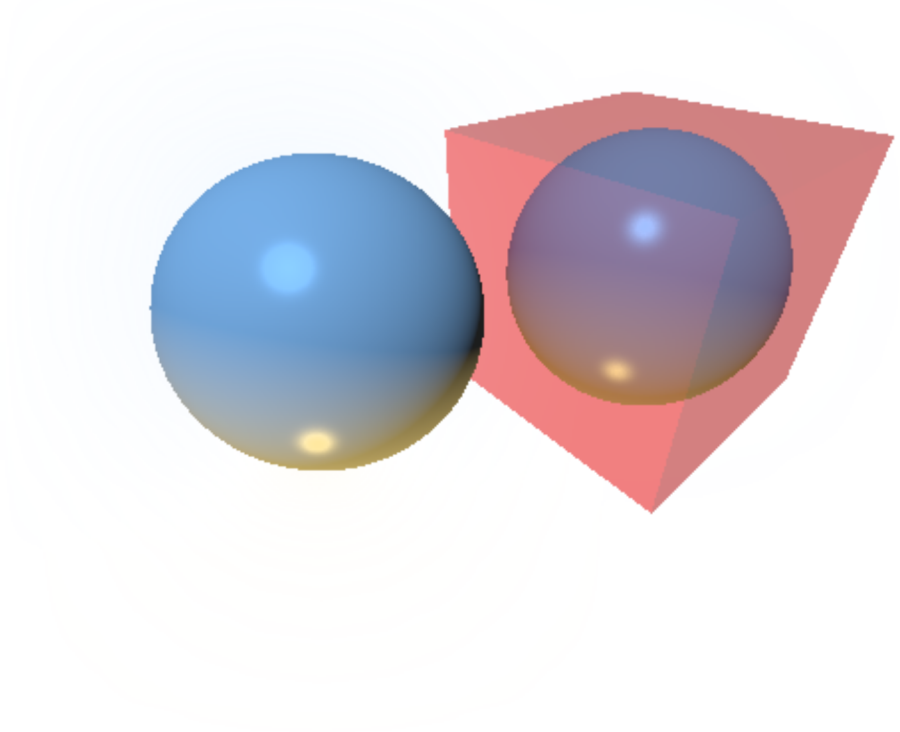

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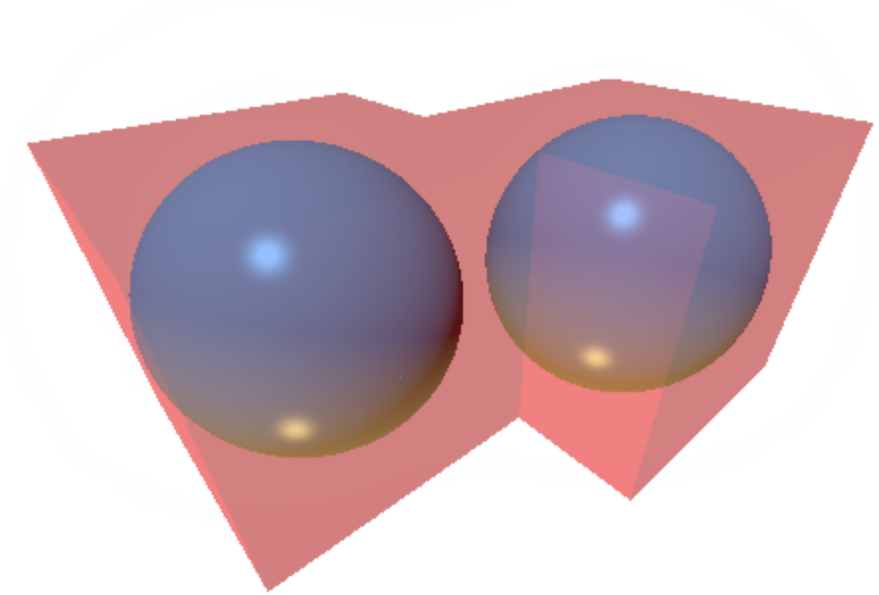

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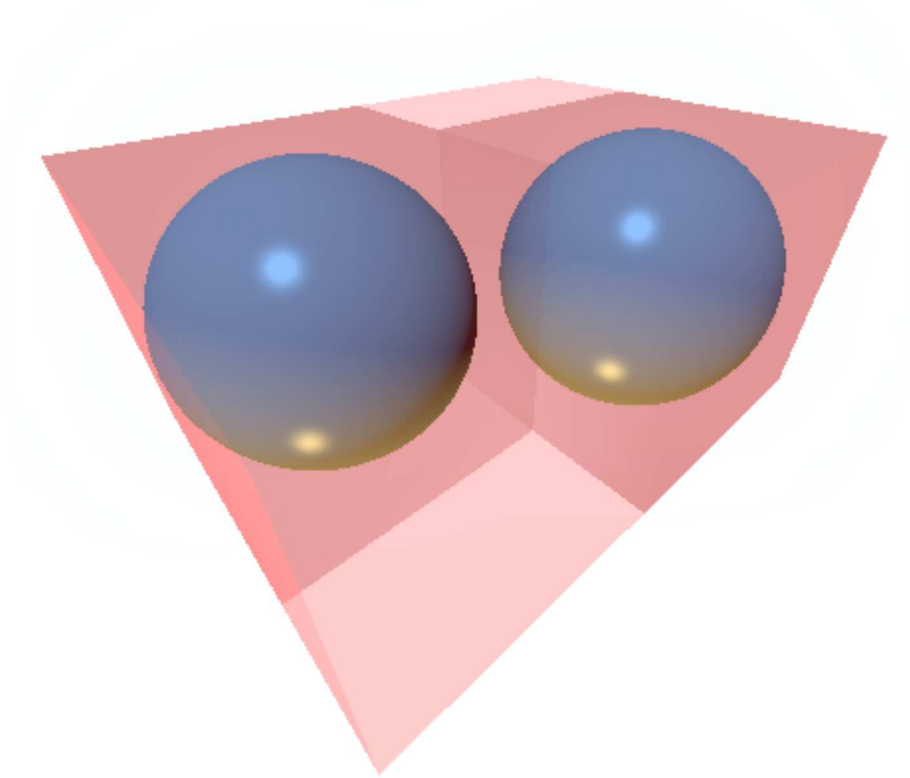

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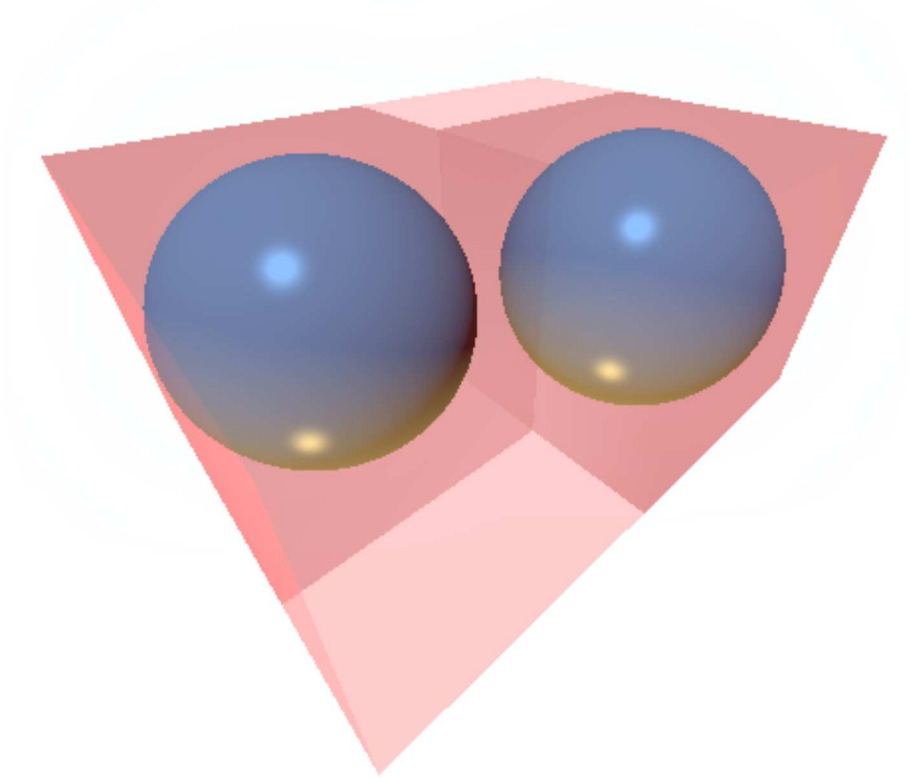

Most databases are bounding hierarchies, and almost all are *trees*

Mostly Functional Engine API

Computations

```
(make-shape ...)
(make-light ...)
(scene-union ...)
(scene-transform ...)
(draw-scene! ...)
```

3D Engine

Combinators

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Awesome! Let’s Try It!

```
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```

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```
> (define unit-sphere
    (shape->scene
     (make-sphere-shape identity-flt3
                        (flvector 1.0 1.0 1.0 1.0)
                        (flvector 0.0 1.0 0.0 2.0)
                        (material 0.01 0.29 0.7 0.1)
                        #f)))

>
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(scene-node
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 2
 (scene-leaf
  (Nonempty-FlRect3 (flvector -1.0 -1.0 -1.0) (flvector 1.0 1.0 1.0))
  1
  (sphere-shape (flidentity3) (flvector 1.0 1.0 1.0 1.0) (flvector 0.0 1.0 0.0 2.0)
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  (flaffine3 (flvector 1.0 0.0 0.0 1.0 0.0 1.0 0.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 0.0 1.0))
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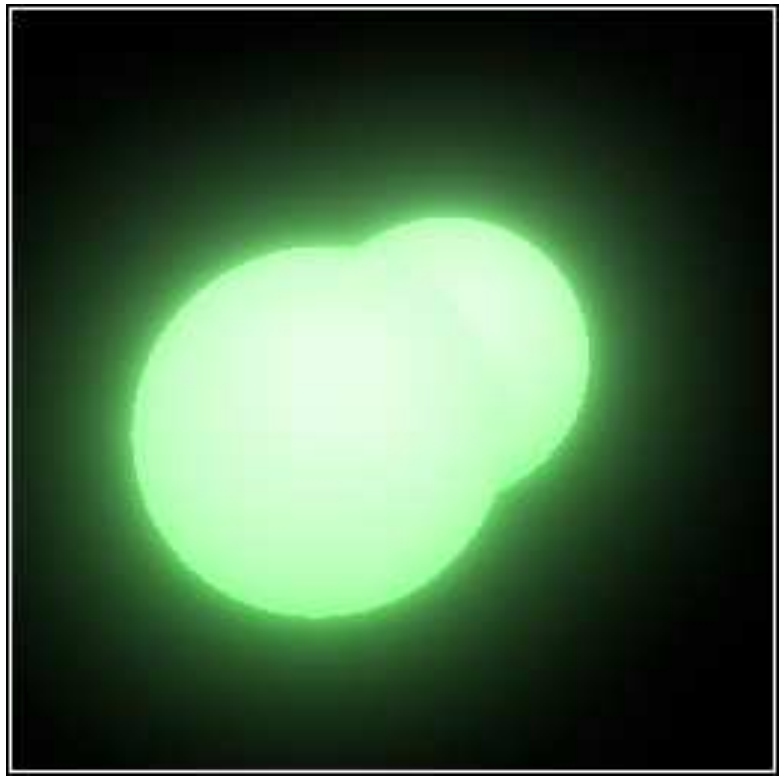

Demos

Design Goals

- Make it fast
  - May require users to tweak, cache, give hints
  - Makes the high-powered blender unsafe and impure

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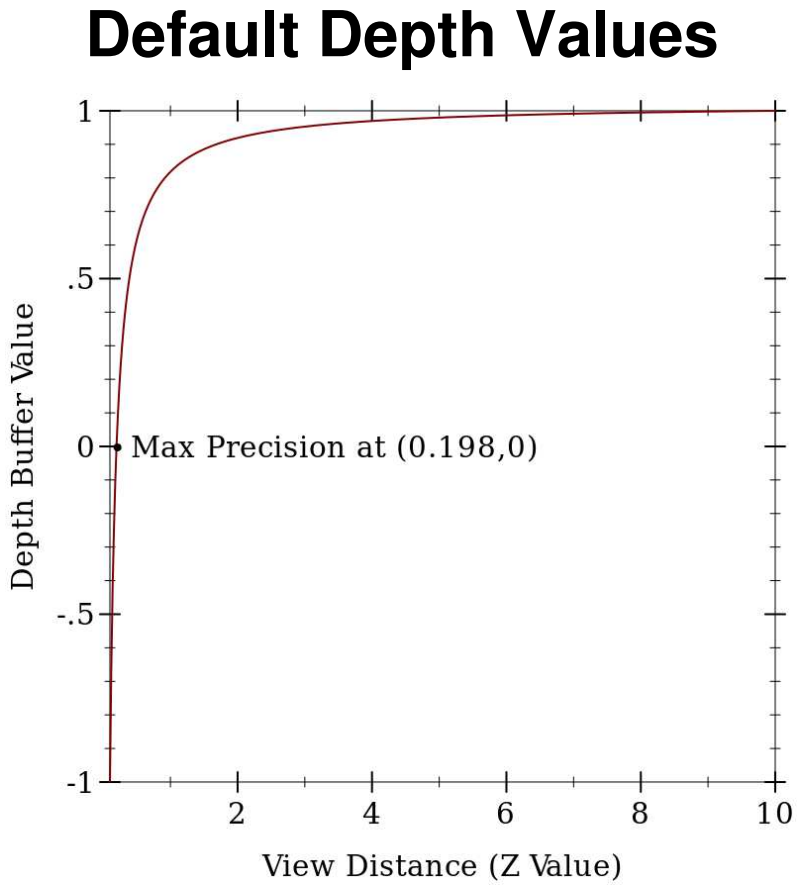
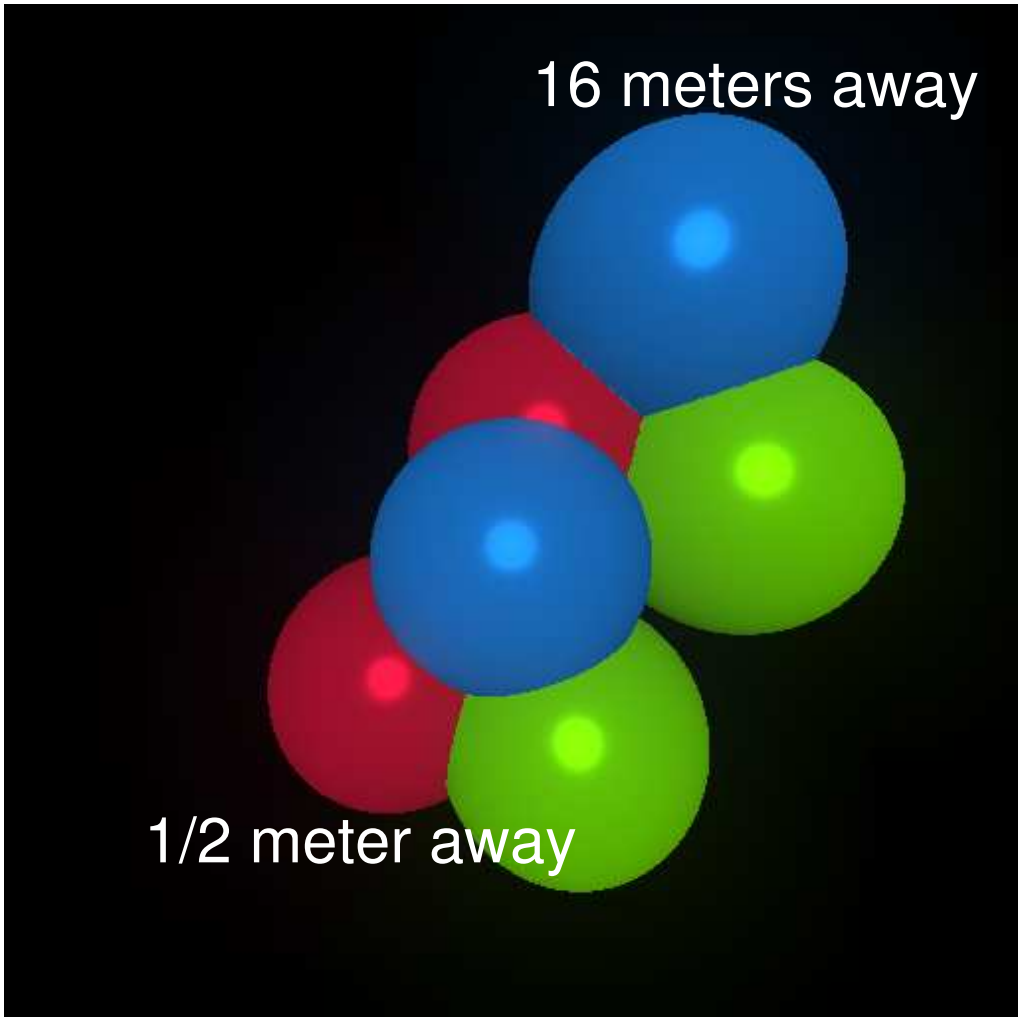
- Use and allow modern rendering techniques (i.e. make it cool)
- Minimize confusing surprises
- Last two goals are often complementary

Default Depth Buffer

`z-near` = **`0.1`** and **`z-far`** = **`10.0`**



Default Depth Buffer: Confusing Surprises



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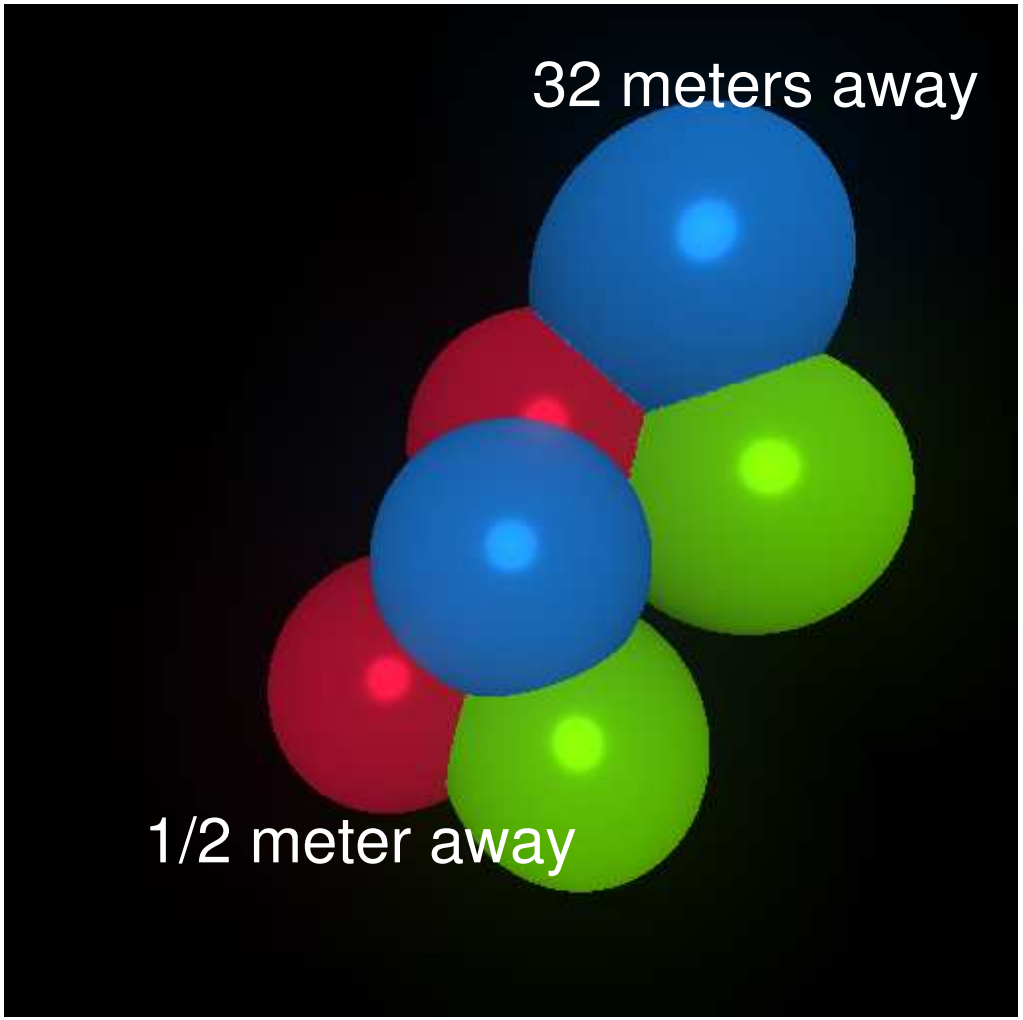

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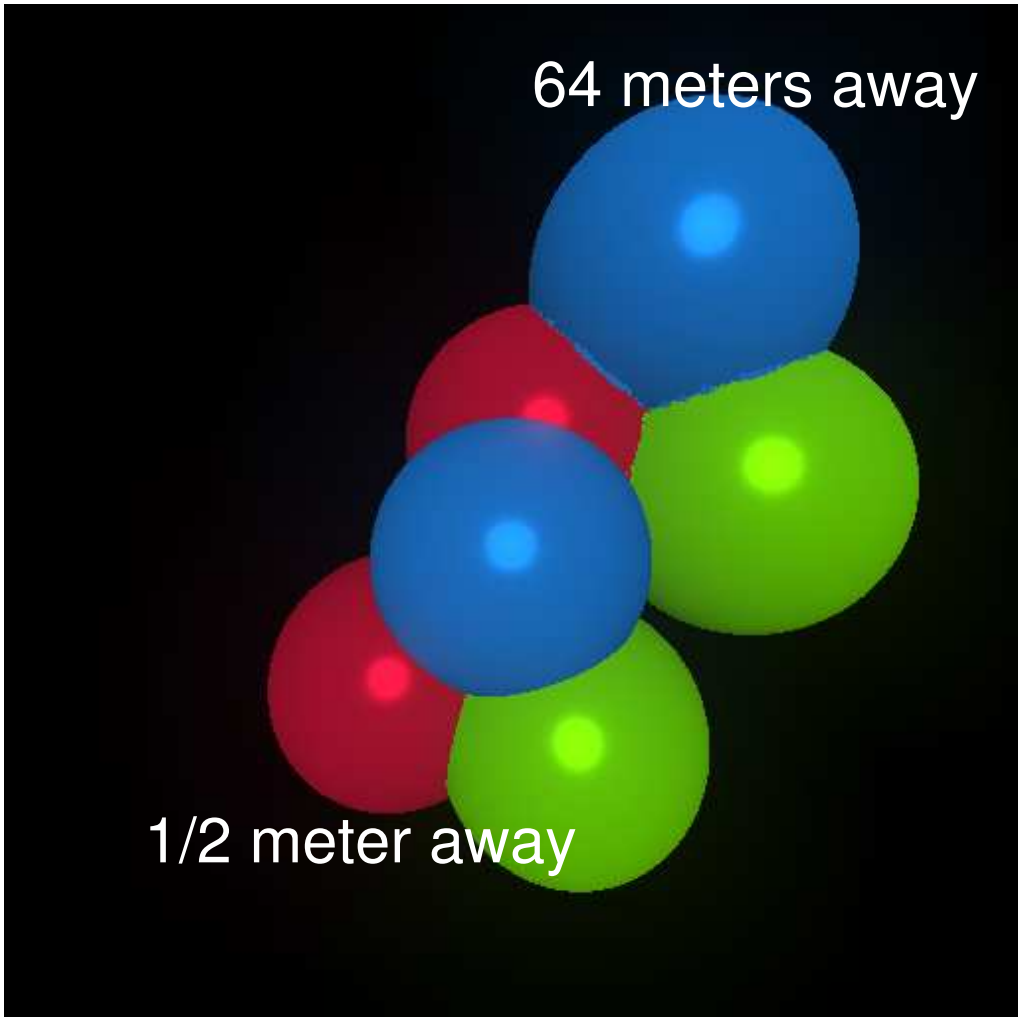

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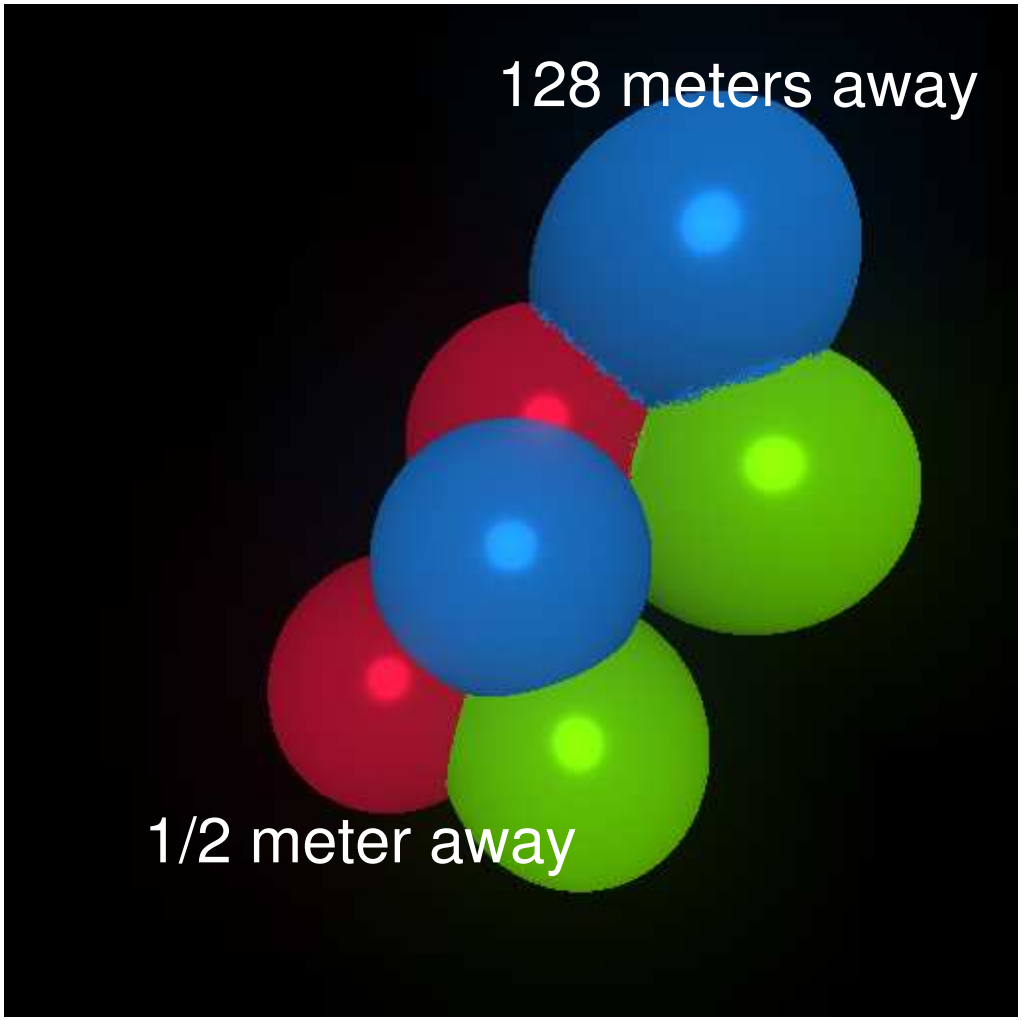

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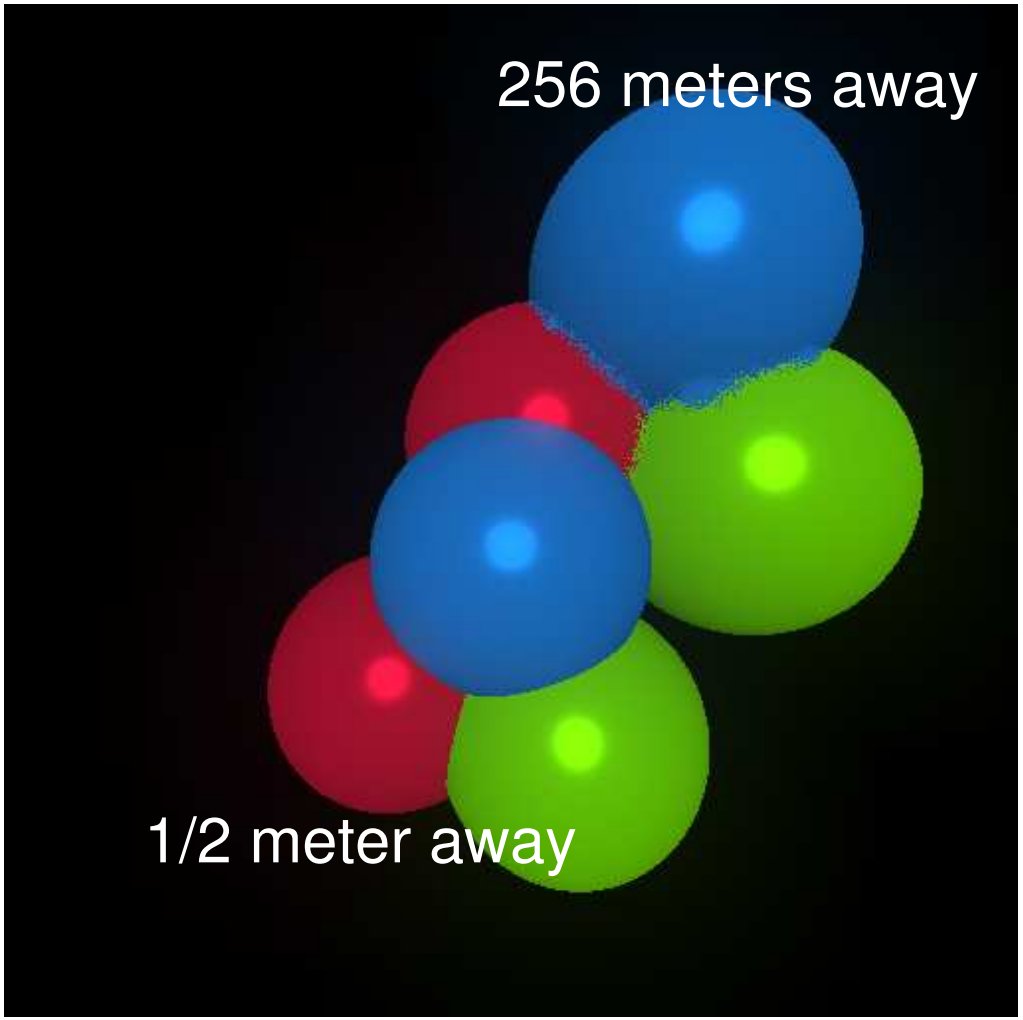

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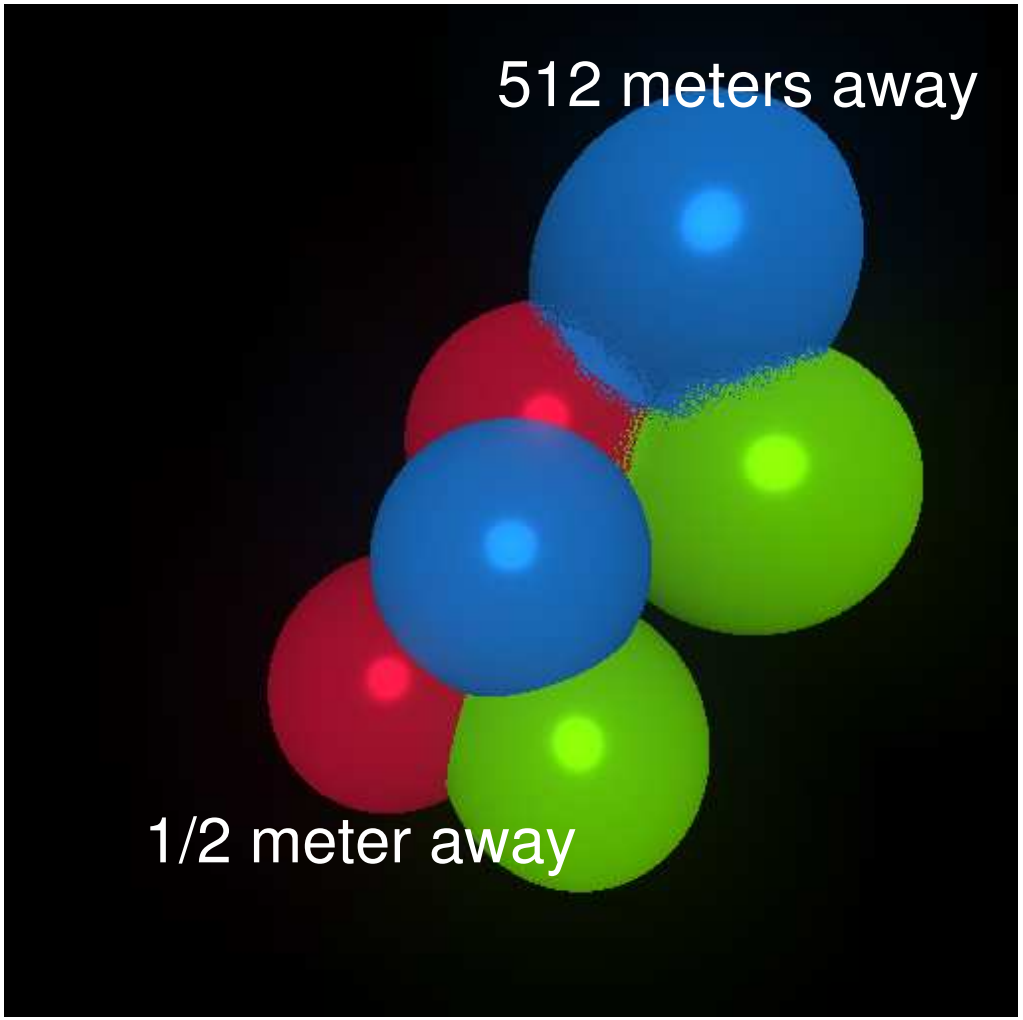

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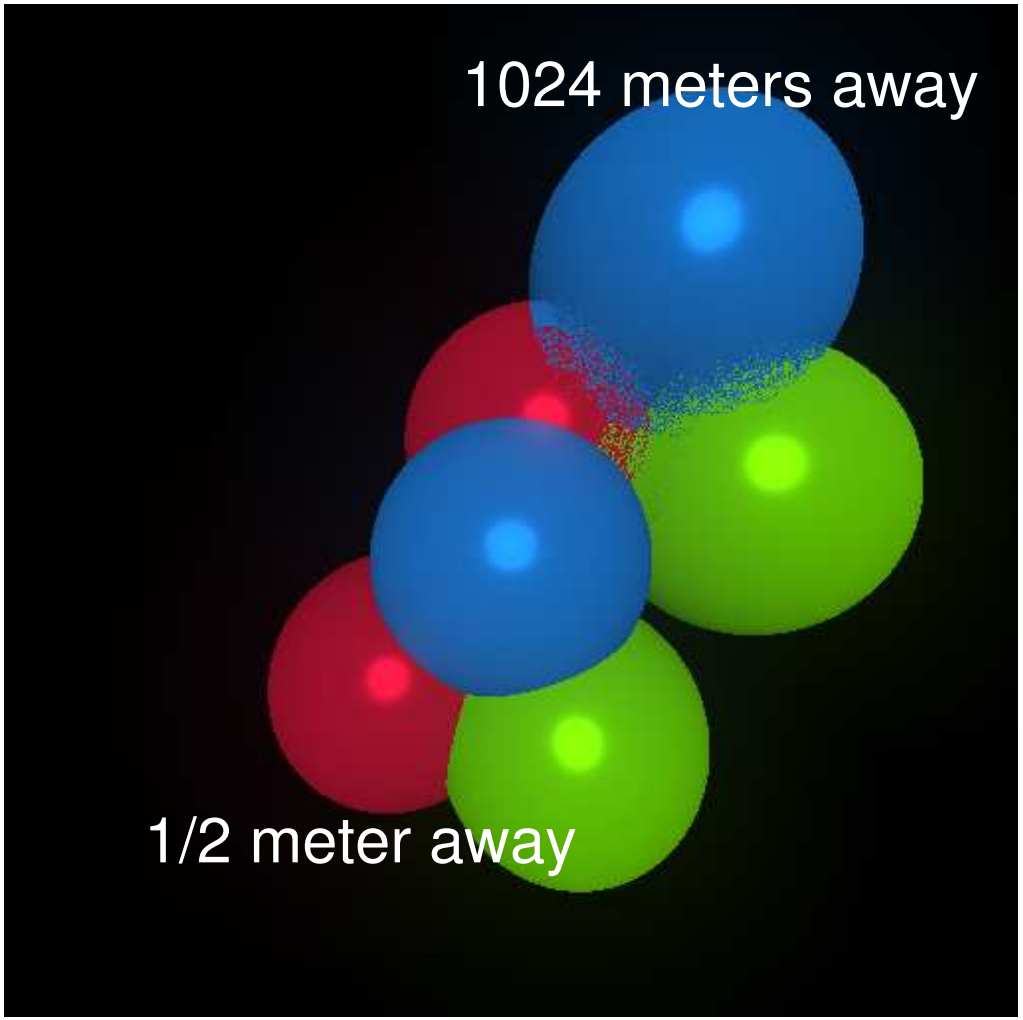

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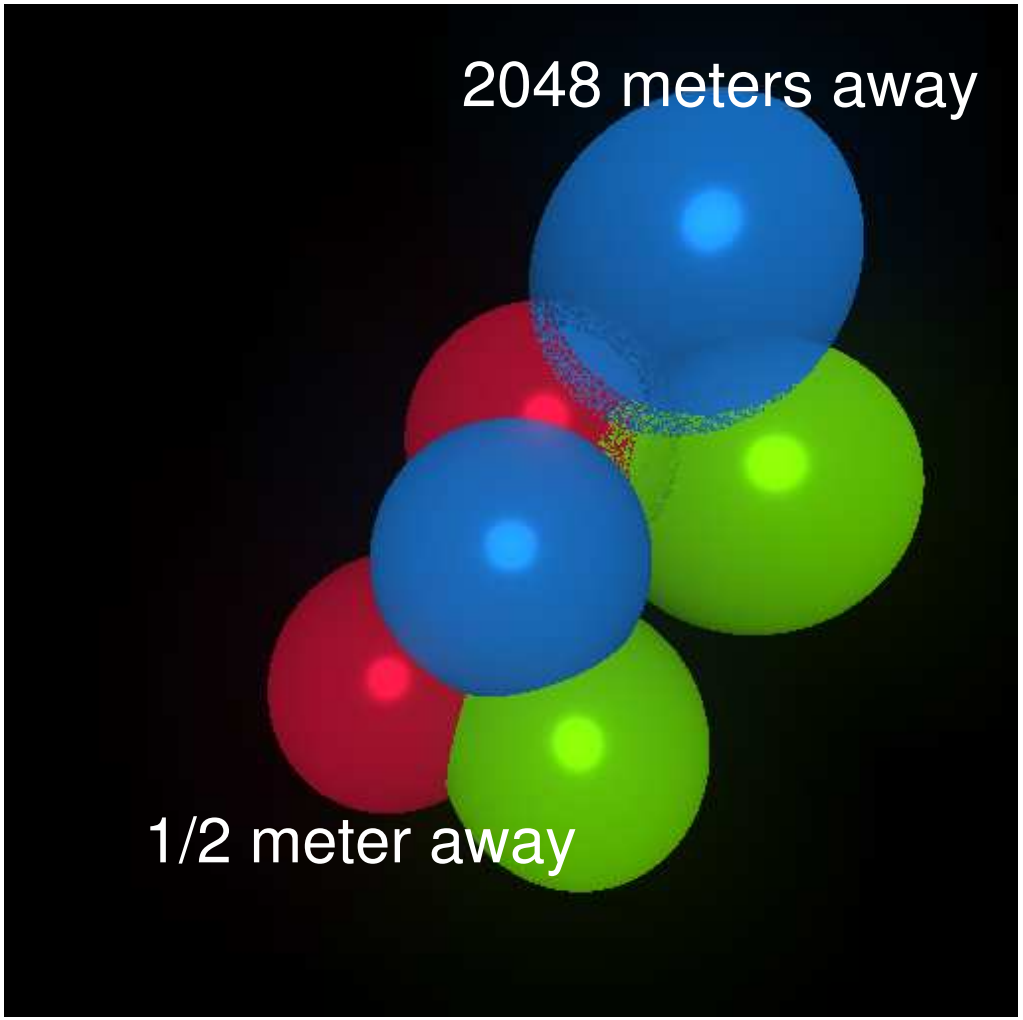

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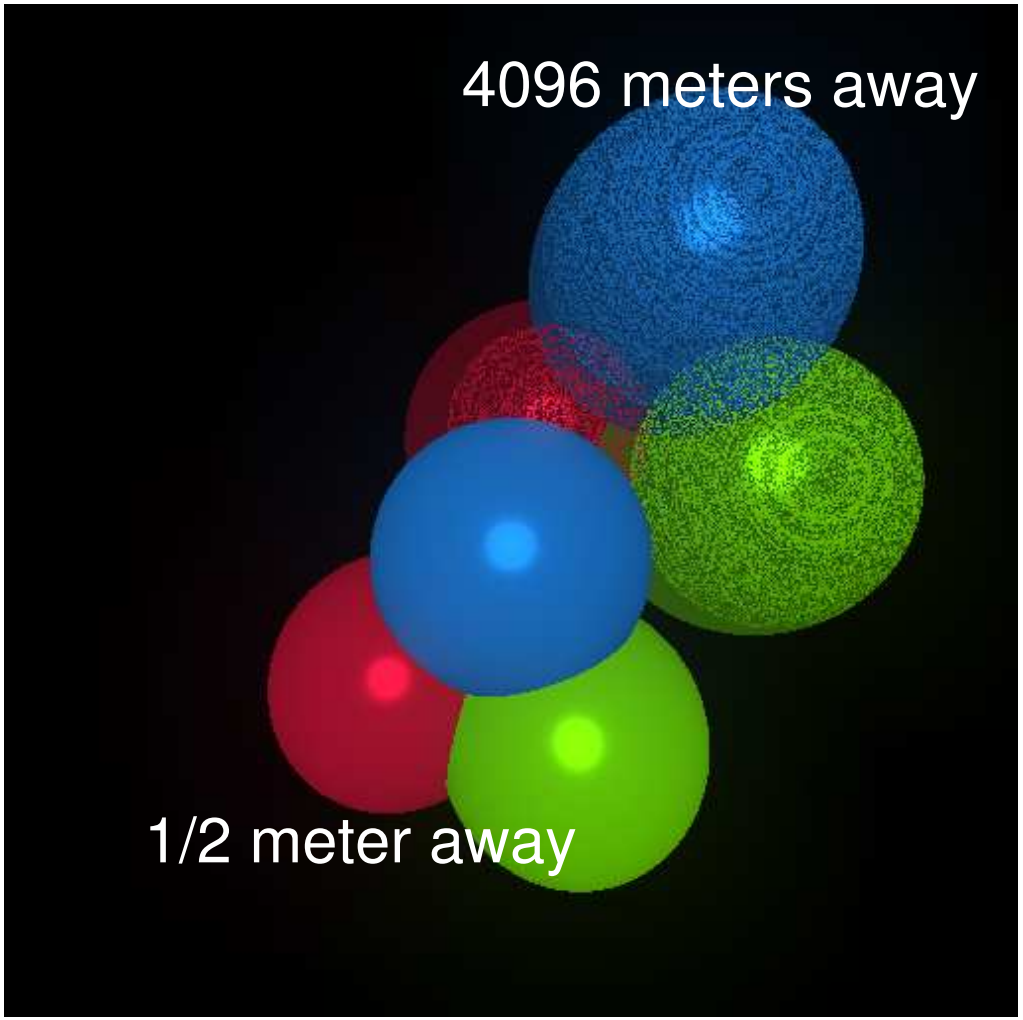

Logarithmic Depth Buffer

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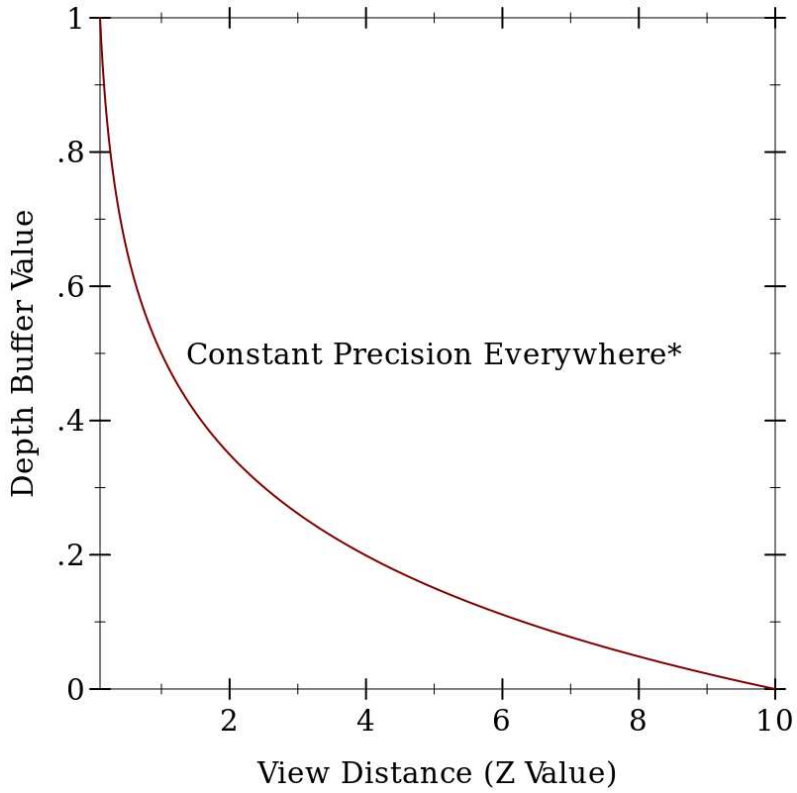
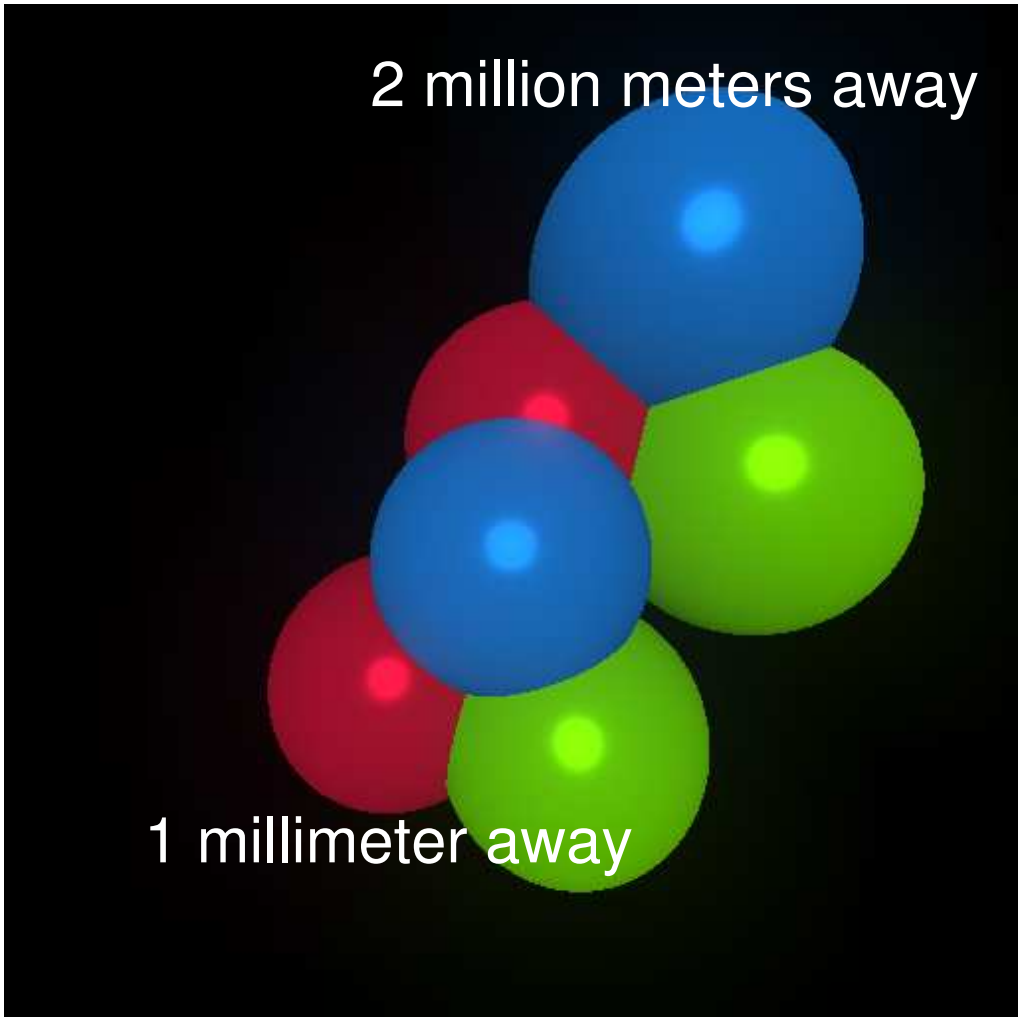
Logarithmic Depth Values



*** http://tulrich.com/geekstuff/log_depth_buffer.txt**

Logarithmic Depth Buffer: Results



Multi-Pass Rendering

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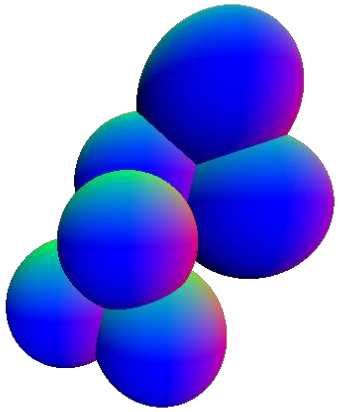
Material: draw shape normals



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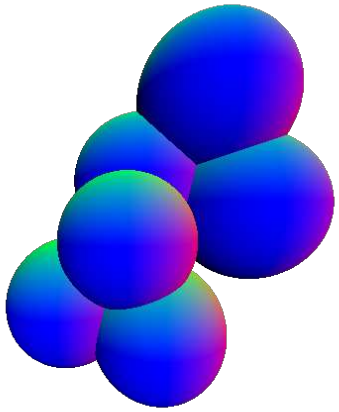

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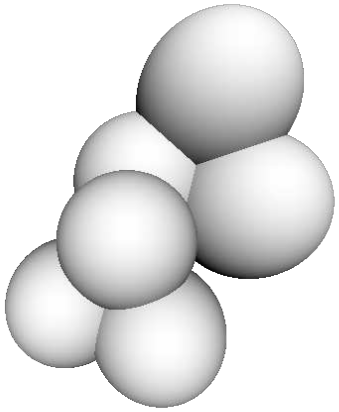

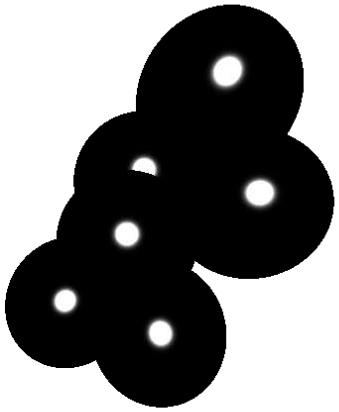

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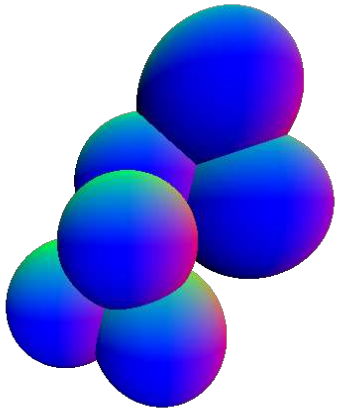

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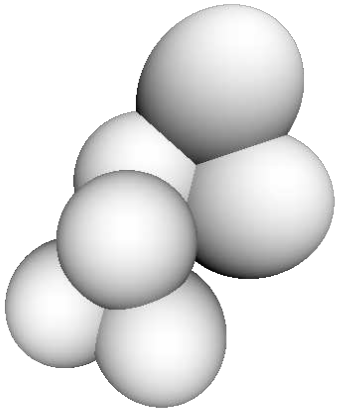
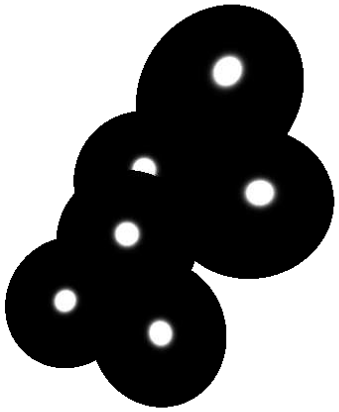
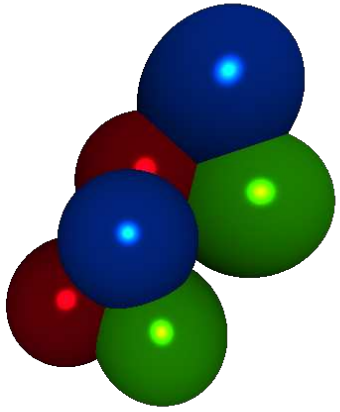




Color: draw shape colors



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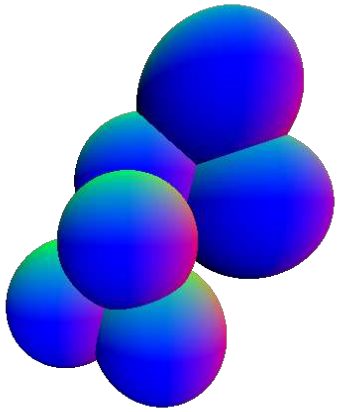

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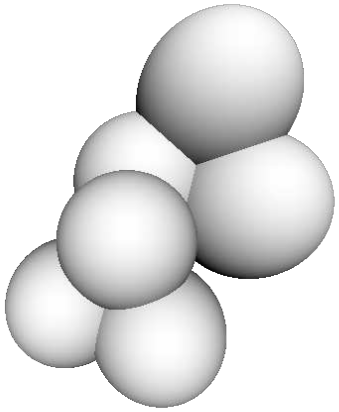

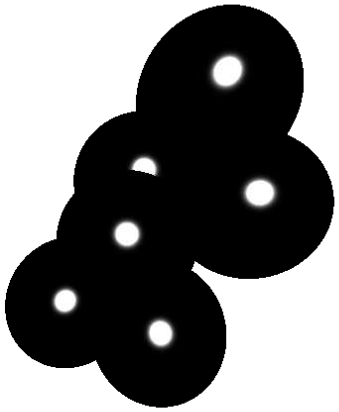

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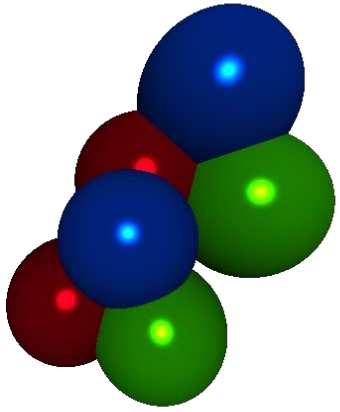
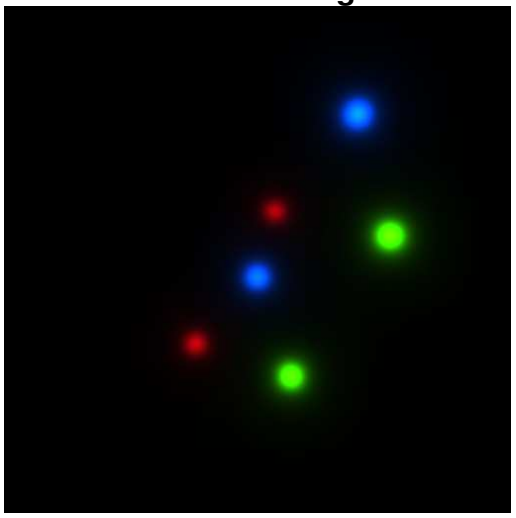


Bloom: extract overbright and blur



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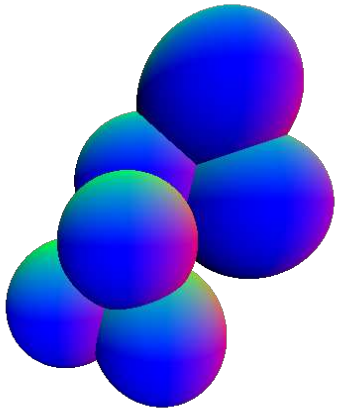

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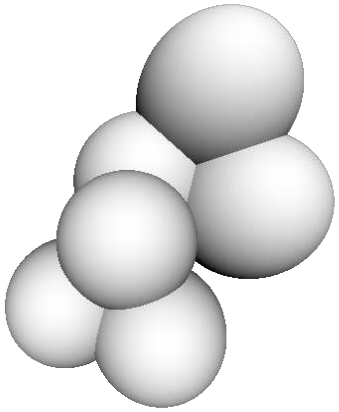

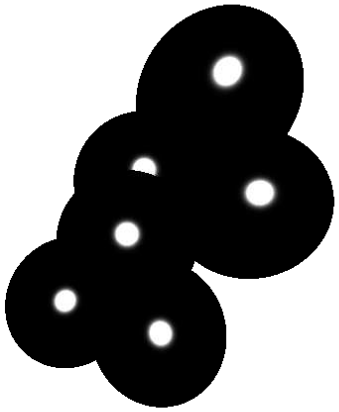

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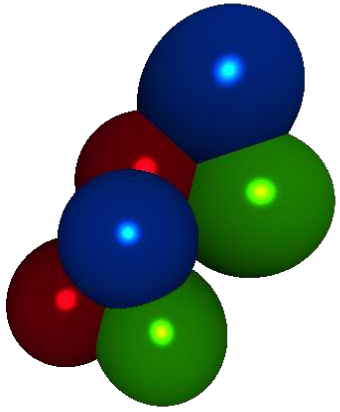

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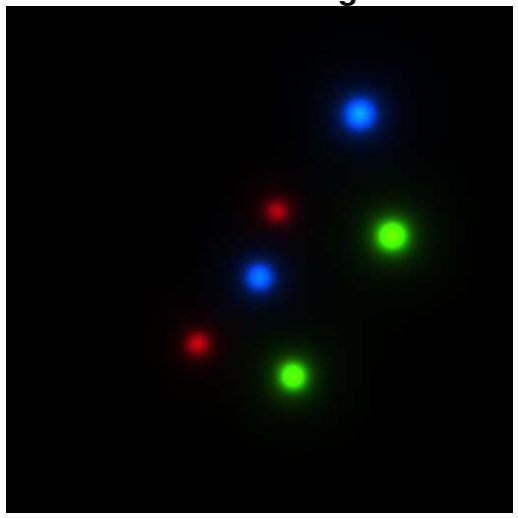
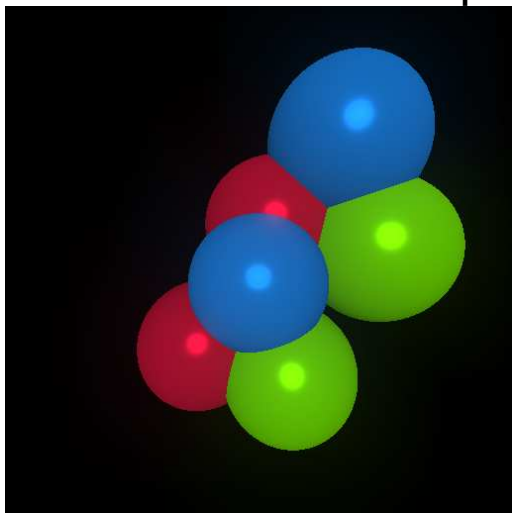
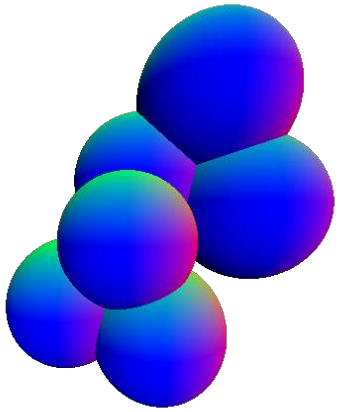


Final: combine and tone-map

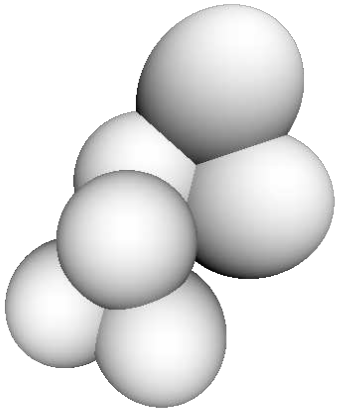


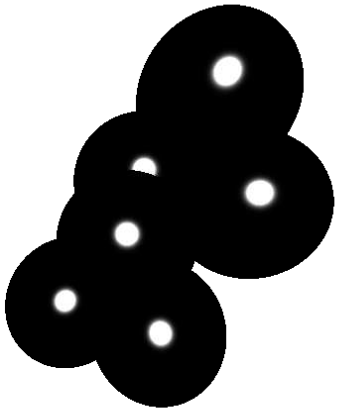
Multi-Pass Rendering

Material: draw shape normals

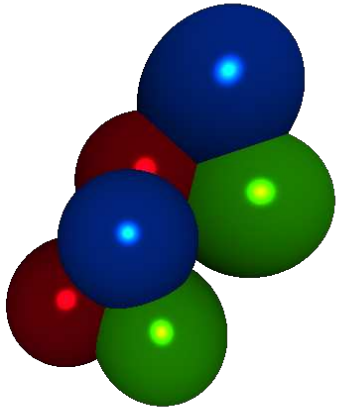


Lighting: draw illumination (diffuse and specular)

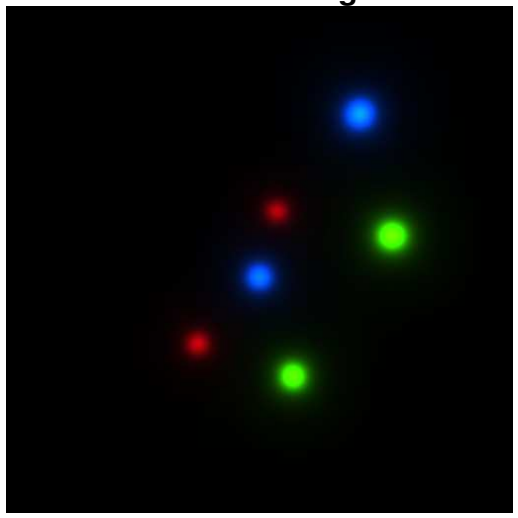




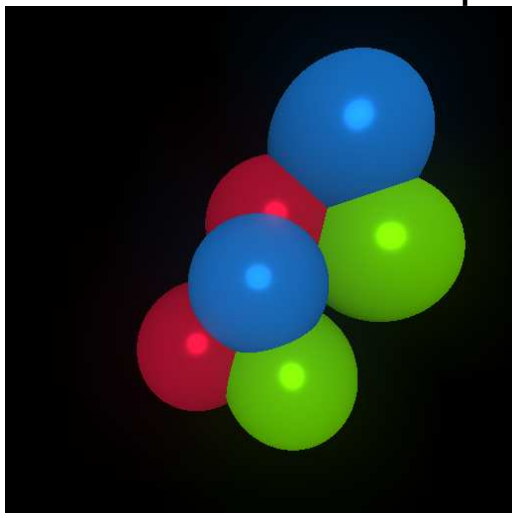
Color: draw shape colors



Bloom: extract overbright and blur



Final: combine and tone-map



O(m+n) in the number of shapes and lights

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- Don’t need to worry about the state of the scene or engine
- Other advantages to full persistence
  - `printf` debugging is crazy useful
  - Store scenes to rewind a game or record a demo

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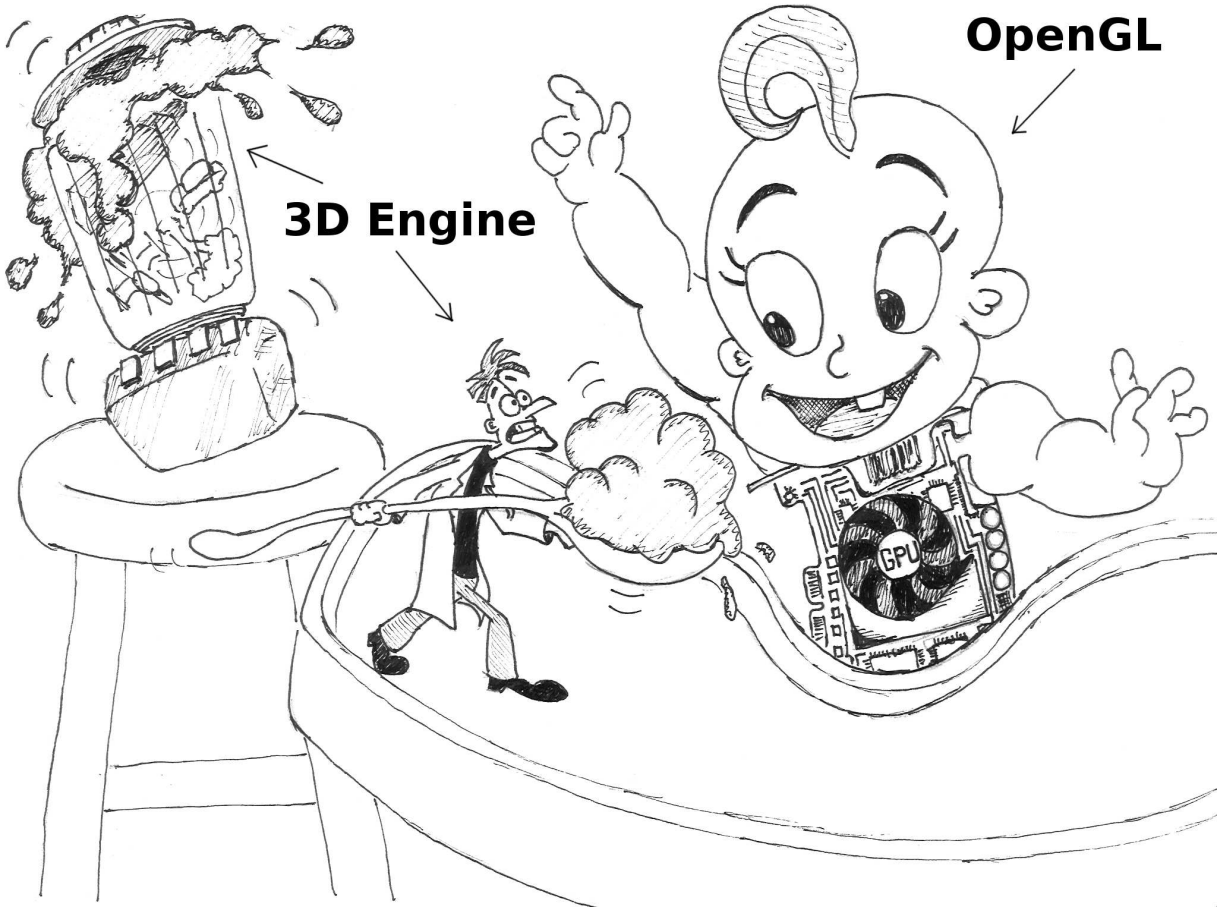
- Faster faster faster faster faster

Install It Today!

Let **`pict3d`** spoon-feed the giant baby for you




```
raco pkg install pict3d
```