

Computer Animation:
Past, Present, and Future

Adam Bargteil

University of Maryland, Baltimore County

Hunger (1974)



Star Trek: The Wrath of Khan (1982)



Particle Systems—A Technique for Modeling a Class of Fuzzy Objects

WILLIAM T. REEVES

Lucasfilm Ltd

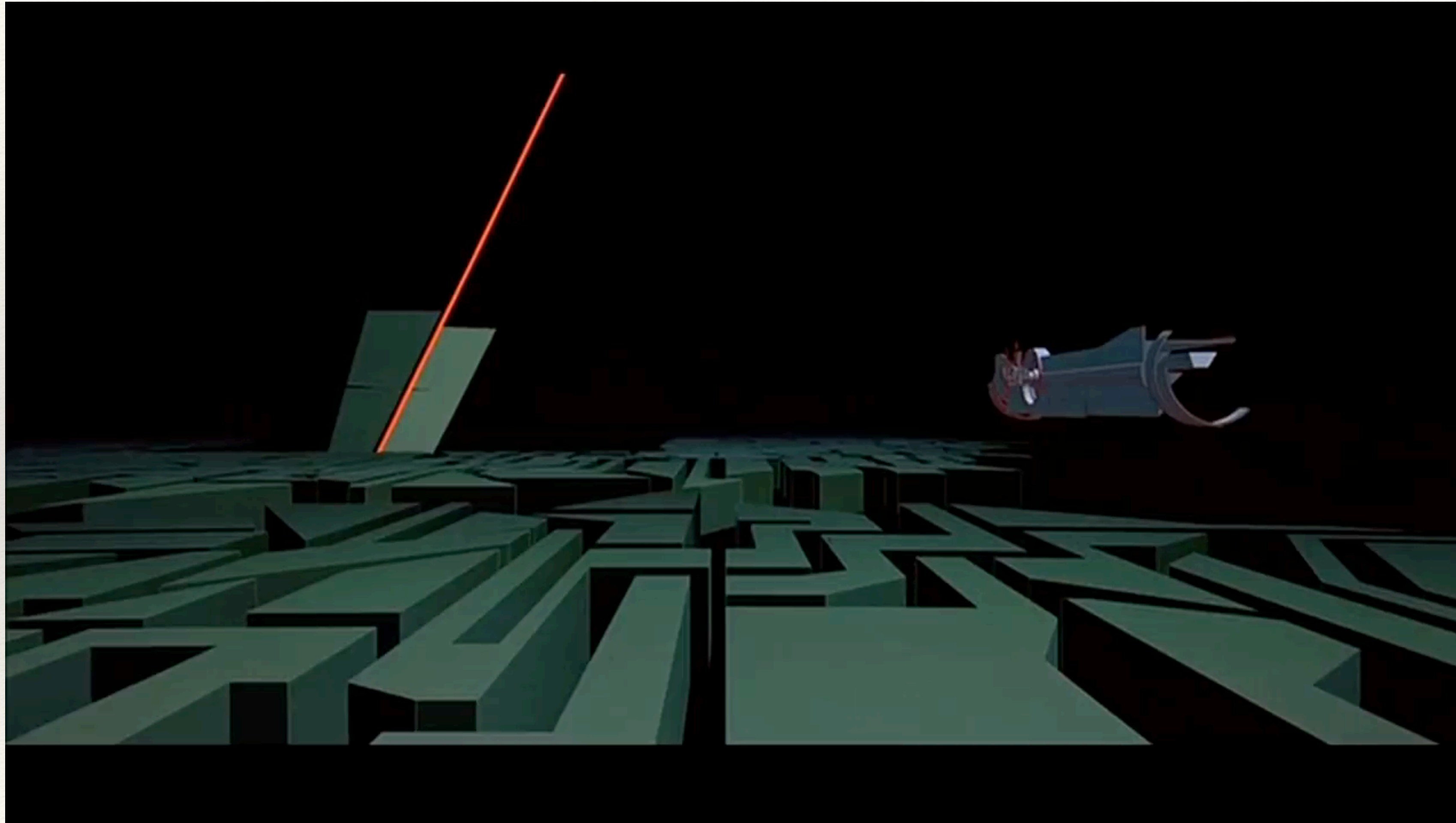
This paper introduces particle systems—a method for modeling fuzzy objects such as fire, clouds, and water. Particle systems model an object as a cloud of primitive particles that define its volume. Over a period of time, particles are generated into the system, move and change form within the system.

Author's address: William T. Reeves, Lucasfilm Ltd, P.O. Box 2009, San Rafael, CA 94912.

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Tron (1982)



Principles of Traditional Animation (1987)



Computer Graphics, Volume 21, Number 4, July 1987

PRINCIPLES OF TRADITIONAL ANIMATION APPLIED TO 3D COMPUTER ANIMATION

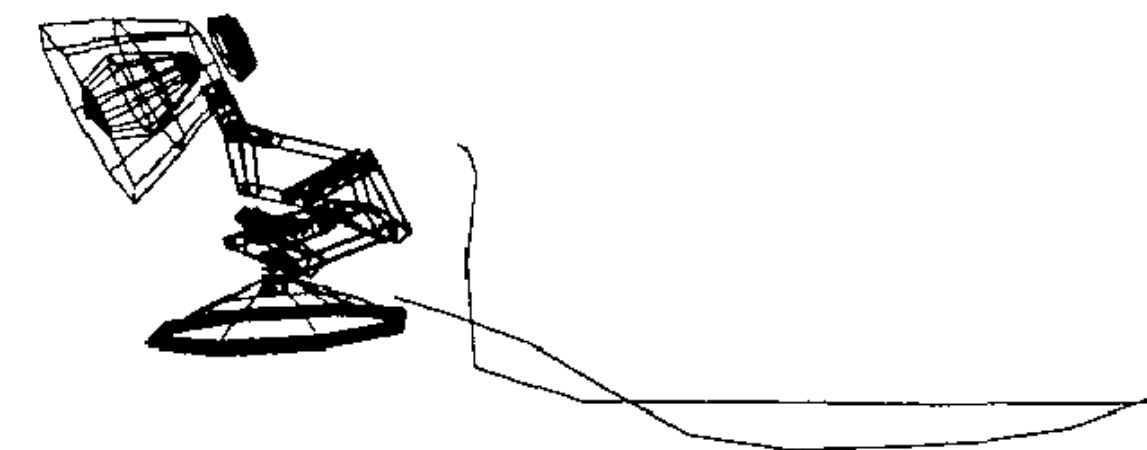
John Lasseter
Pixar
San Rafael
California

"There is no particular mystery in animation... it's really very simple, and like anything that is simple, it is about the hardest thing in the world to do." Bill Tytla at the Walt Disney Studio, June 28, 1937. [14]

ABSTRACT

This paper describes the basic principles of traditional 2D hand drawn animation and their application to 3D computer animation. After describing how these principles evolved, the individual principles are detailed.

FIGURE 1. Luxo Jr.'s hop with overlapping action on cord. Flip pages from last page of paper to front. The top figures are frames 1-5, the bottom are frames 6-10.



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Principles of Traditional Animation (1987)

- ❖ squash and stretch
- ❖ timing
- ❖ anticipation
- ❖ staging
- ❖ follow through & overlapping action
- ❖ straight ahead and pose-to-pose action
- ❖ slow in and out
- ❖ arcs
- ❖ exaggeration
- ❖ secondary action
- ❖ appeal

Jurassic Park (1993)



“it was like one of those moments in history, like the invention of the light bulb or the first telephone call... A major gap had been crossed and things were never going to be the same.”

–George Lucas

Toy Story (1995)

THE FOLLOWING **PREVIEW** HAS BEEN APPROVED FOR
ALL AUDIENCES
BY THE MOTION PICTURE ASSOCIATION OF AMERICA

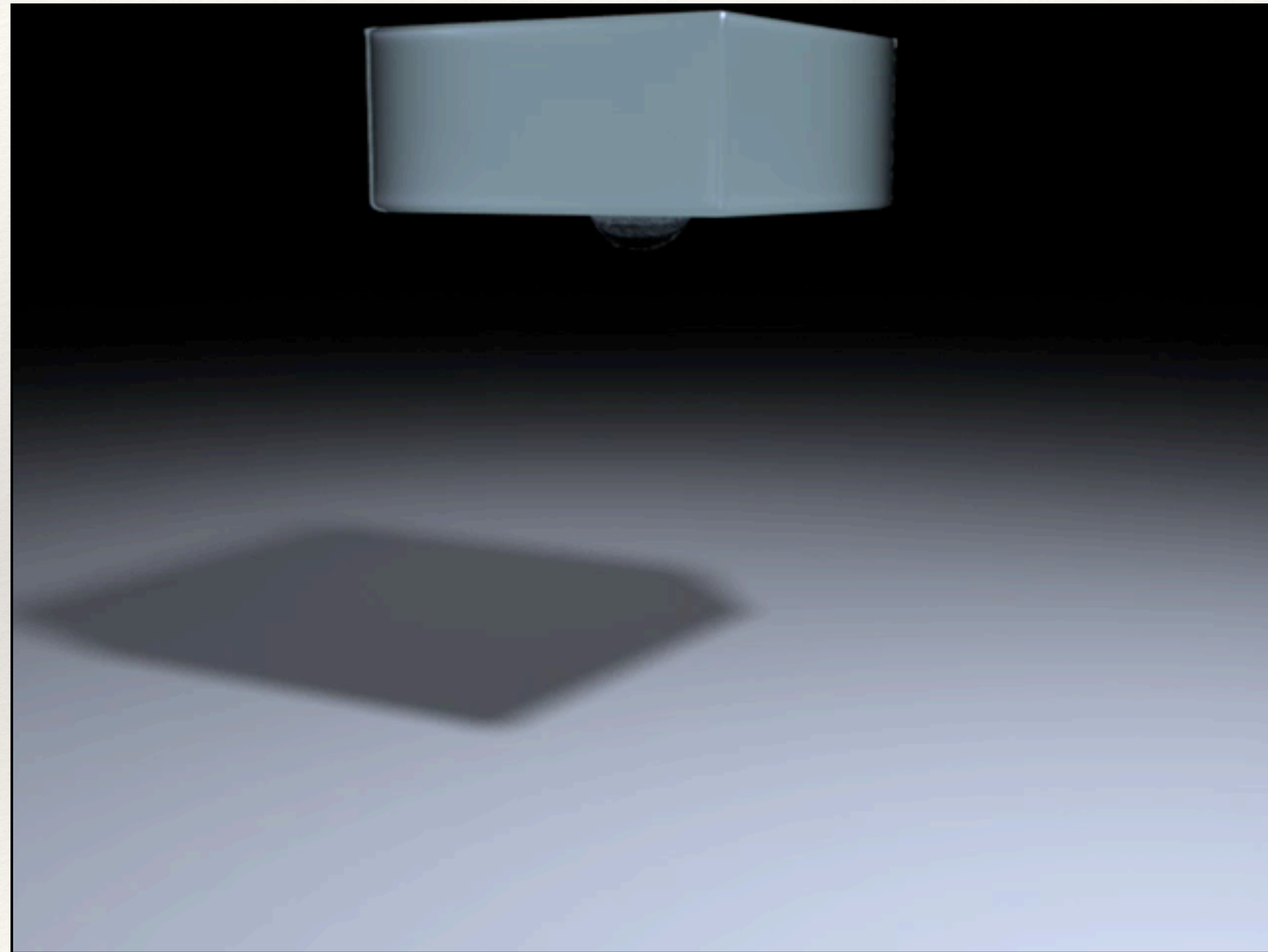
1995-2015

The Golden Age of Computer Animation

The “Special Effects Problem”

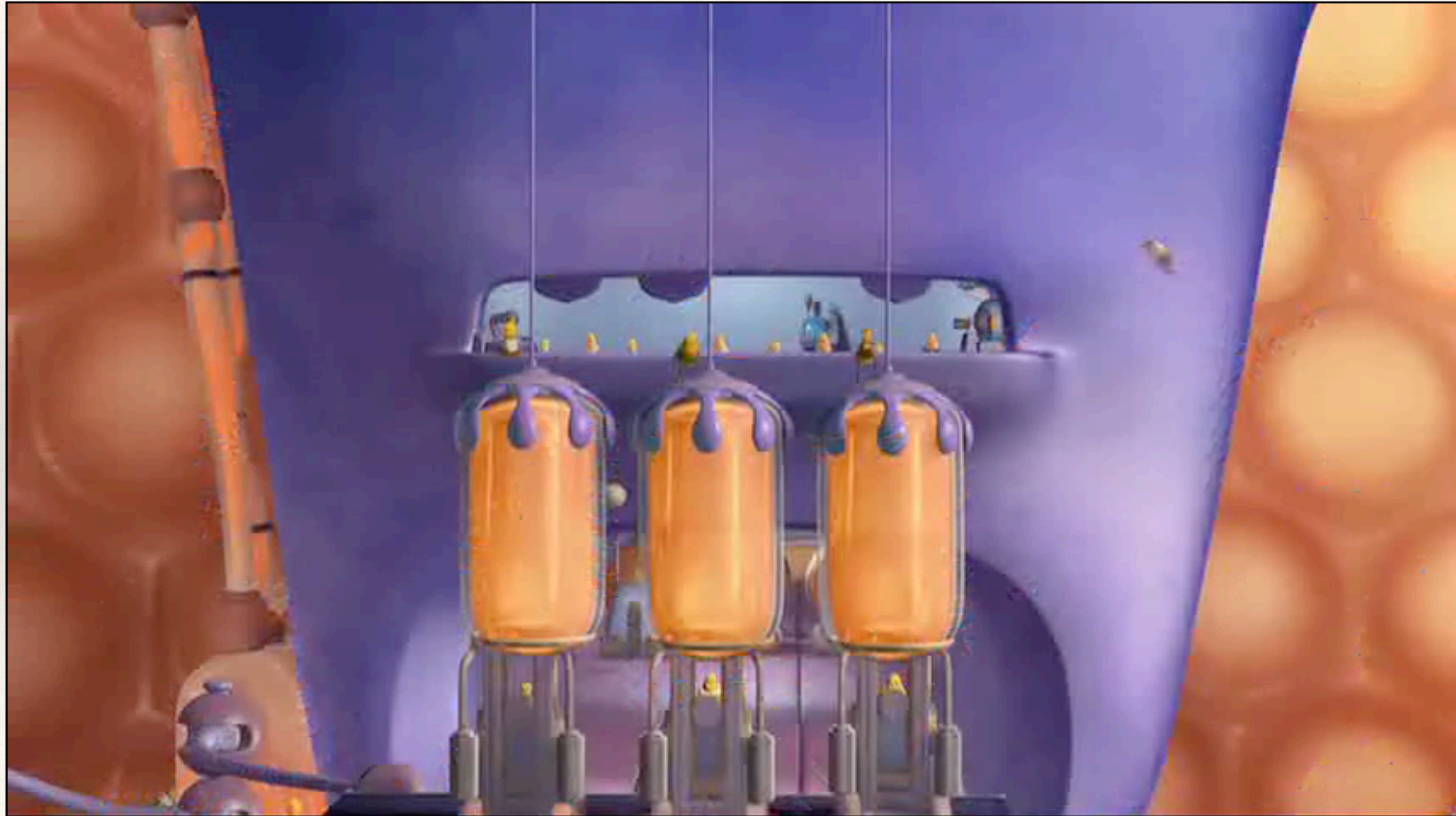
explosions, tidal waves, city buildings destroyed by robots, aliens, supervillains, etc.

Eulerian Viscoelastic Fluids



Goktekin, Bargteil, O'Brien [SIGGRAPH 2004]

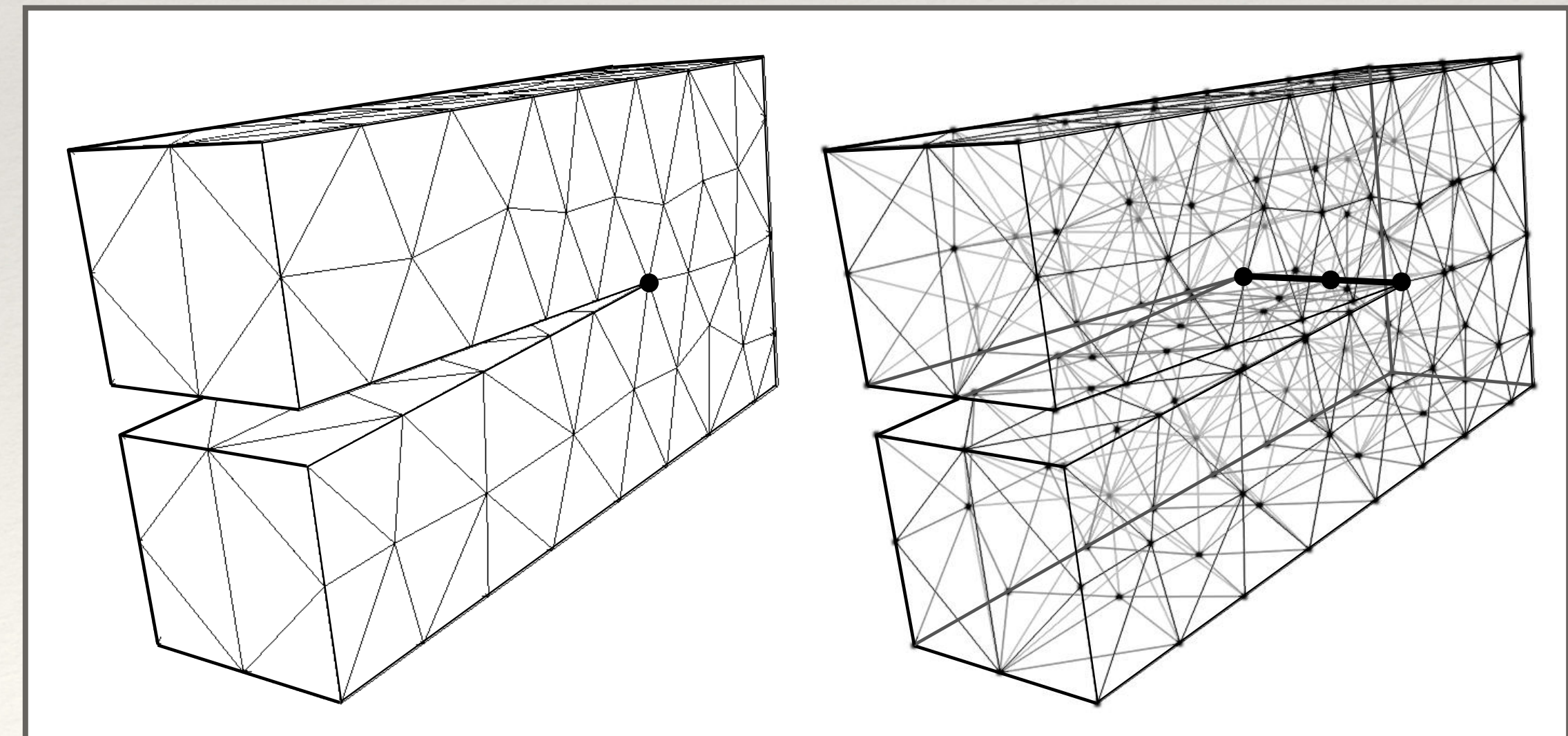
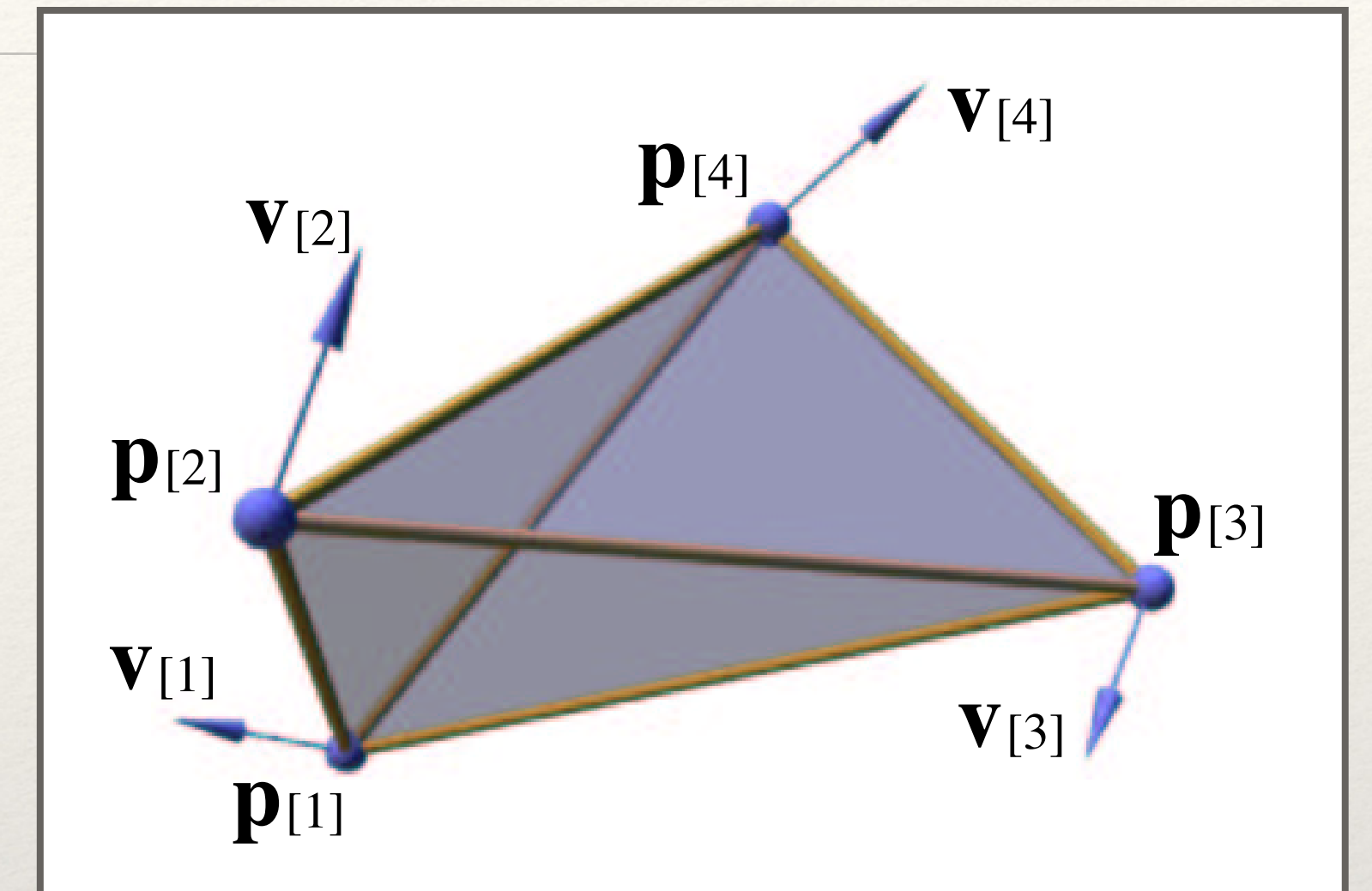
DreamWorks Animation's *Bee Movie* (2007)



Finite Element Destruction: *A Success Story*

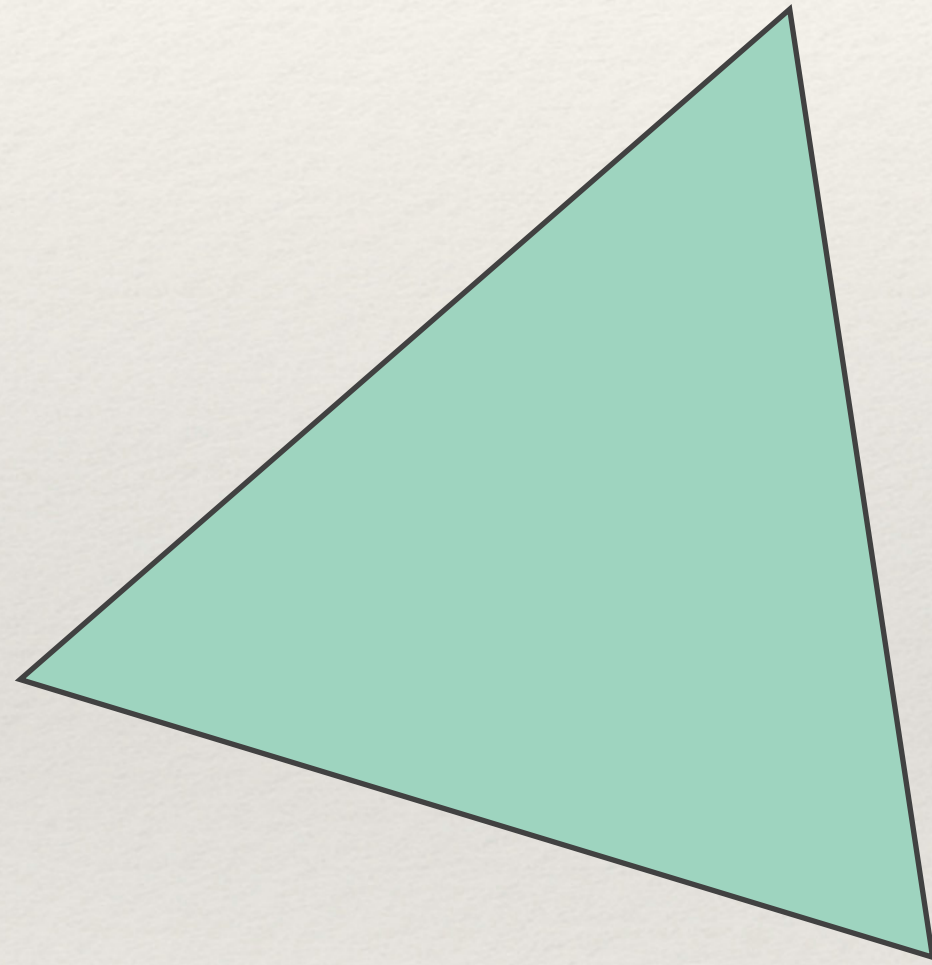
Finite Elements

- ❖ Fundamental physics simulation
 - ❖ Rigid movement
 - ❖ Bending, twisting, stretching
- ❖ Dynamic tearing, cracking, ripping
- ❖ Wide range of materials

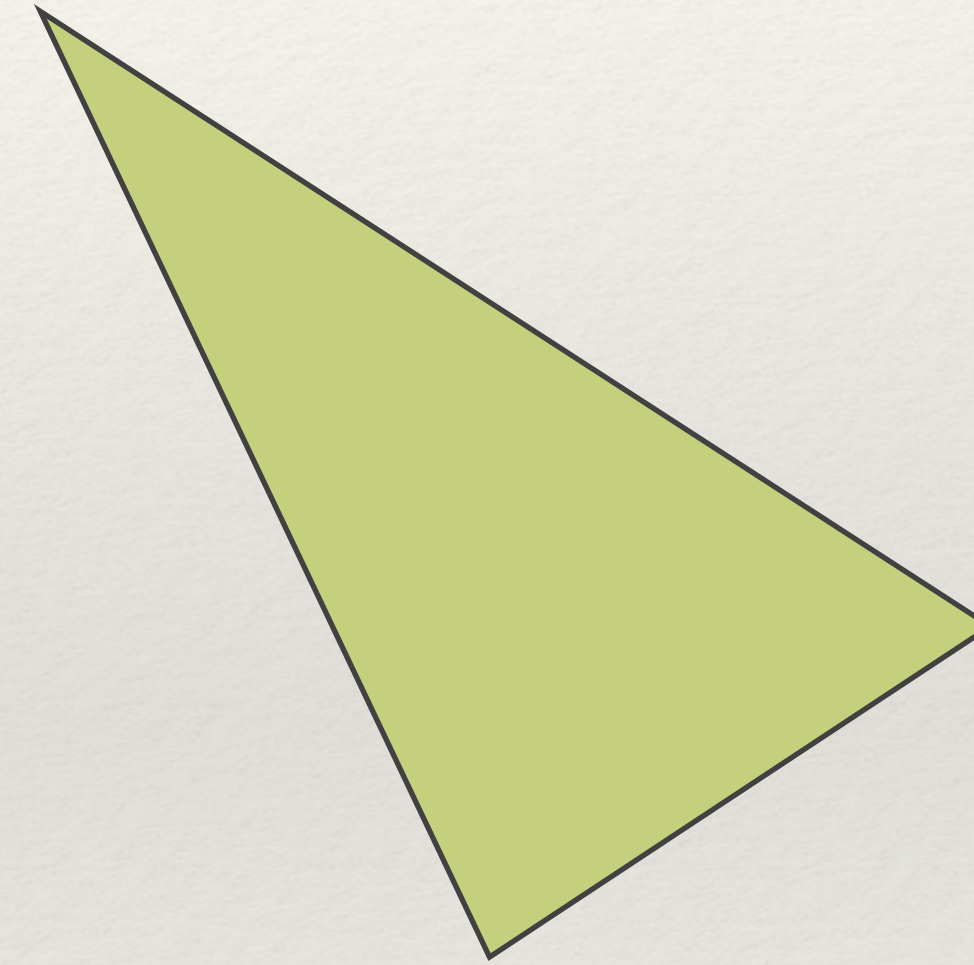


Finite Elements

Rest

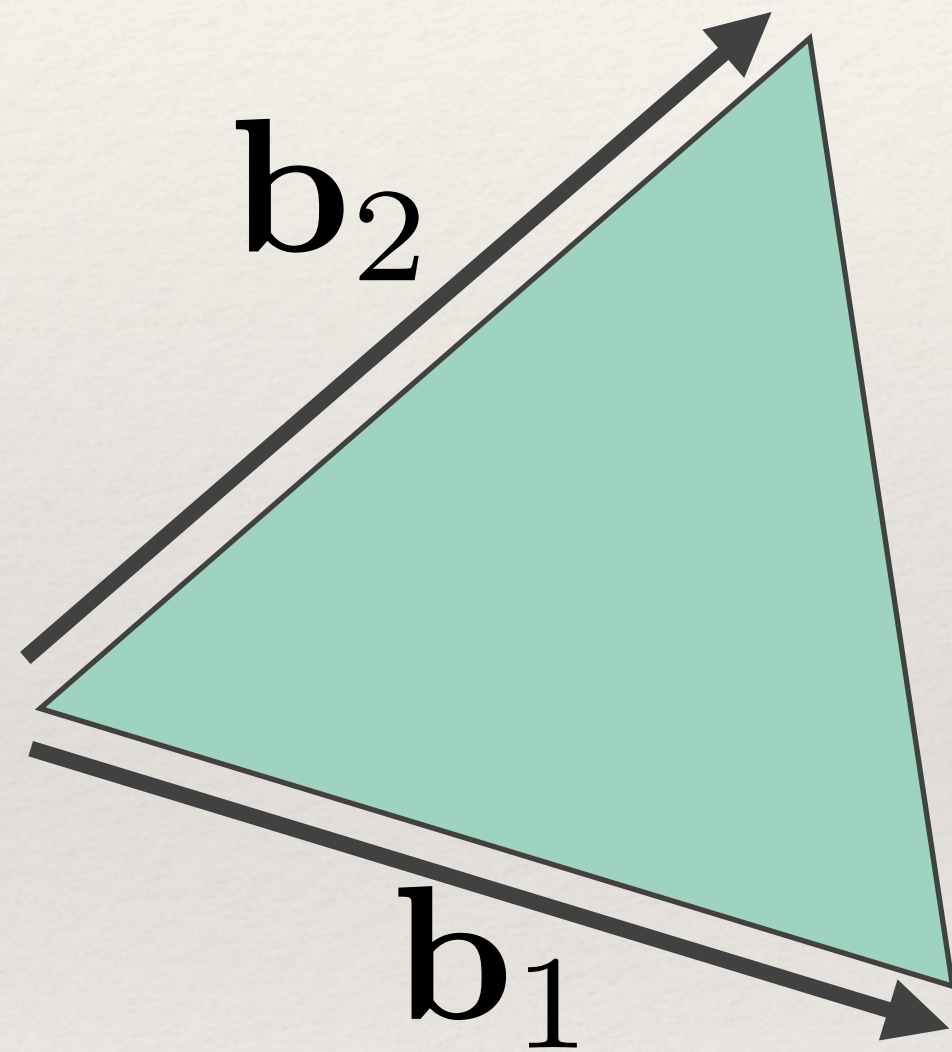


Deformed

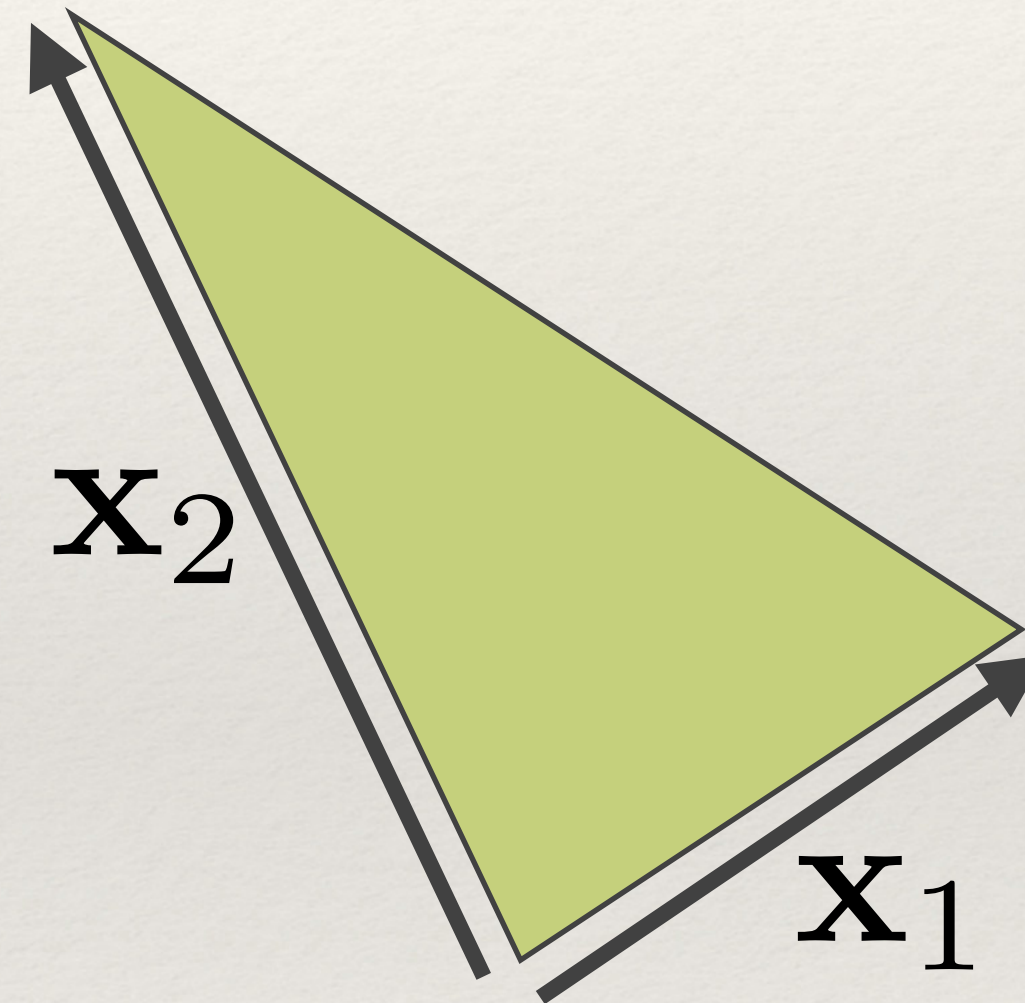


Finite Elements

Rest

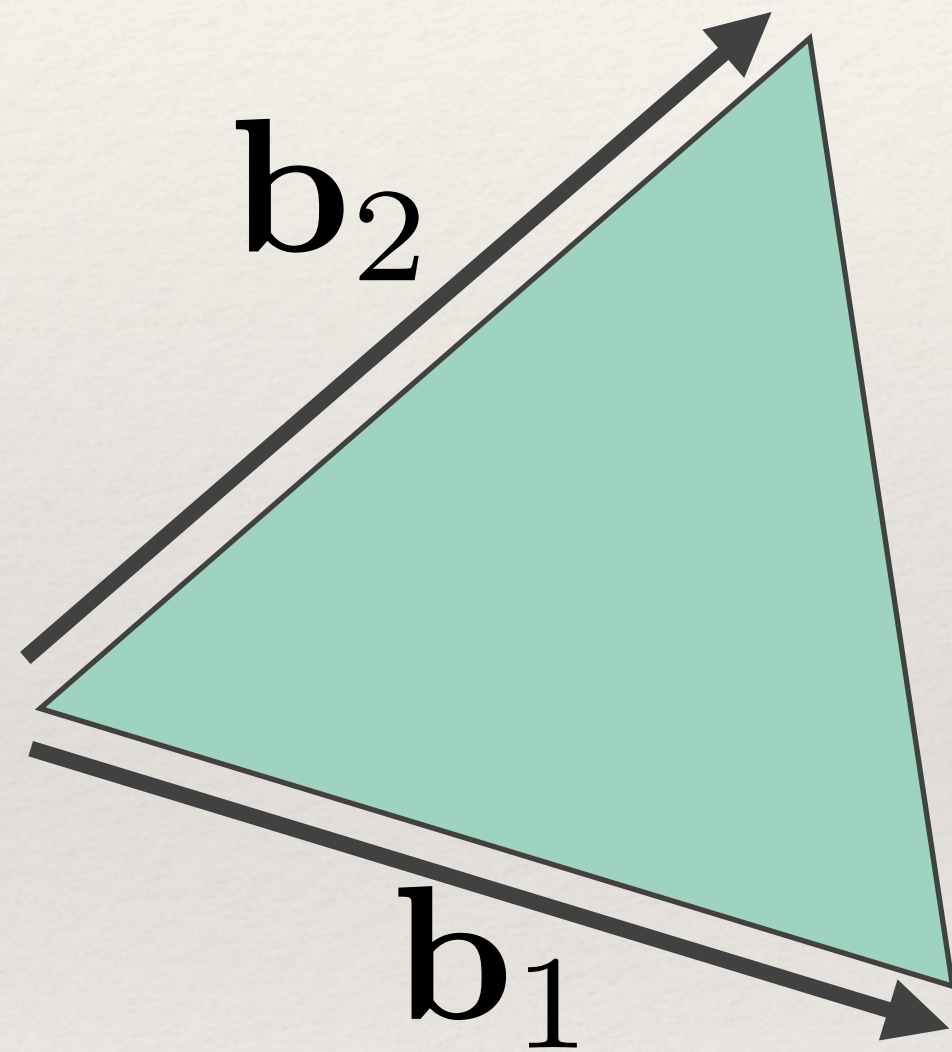


Deformed



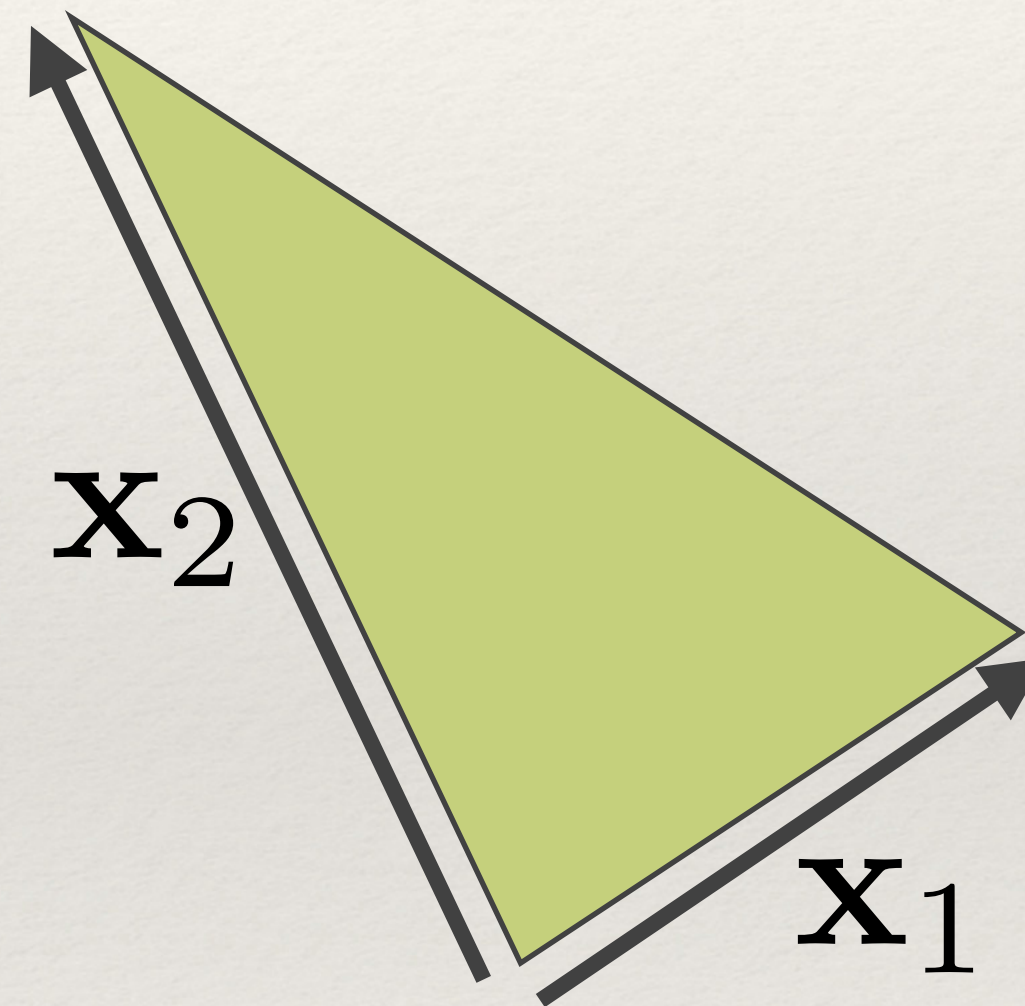
Finite Elements

Rest



$$\beta = (\mathbf{b}_1 \mathbf{b}_2)^{-1}$$

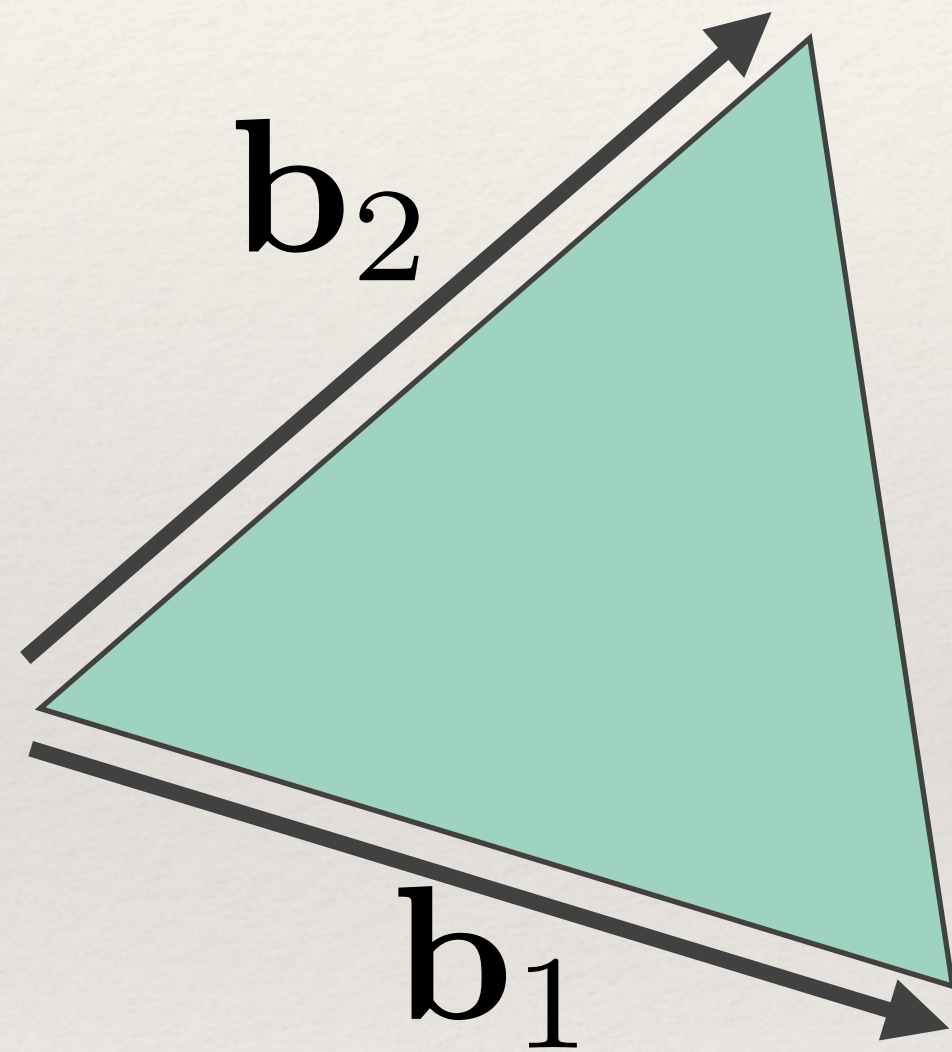
Deformed



$$\mathbf{X} = (\mathbf{x}_1 \mathbf{x}_2)$$

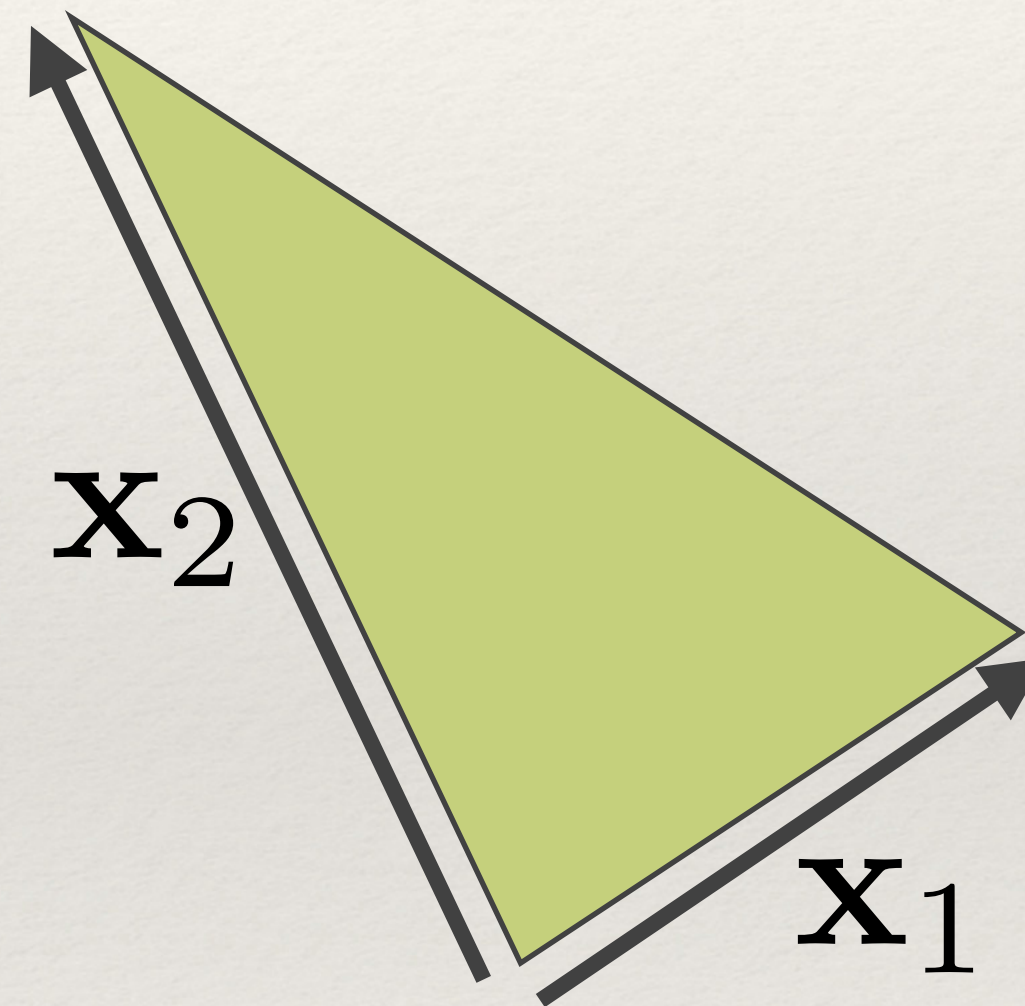
Finite Elements

Rest



$$\beta = (\mathbf{b}_1 \mathbf{b}_2)^{-1}$$

Deformed



$$\mathbf{X} = (\mathbf{x}_1 \mathbf{x}_2)$$

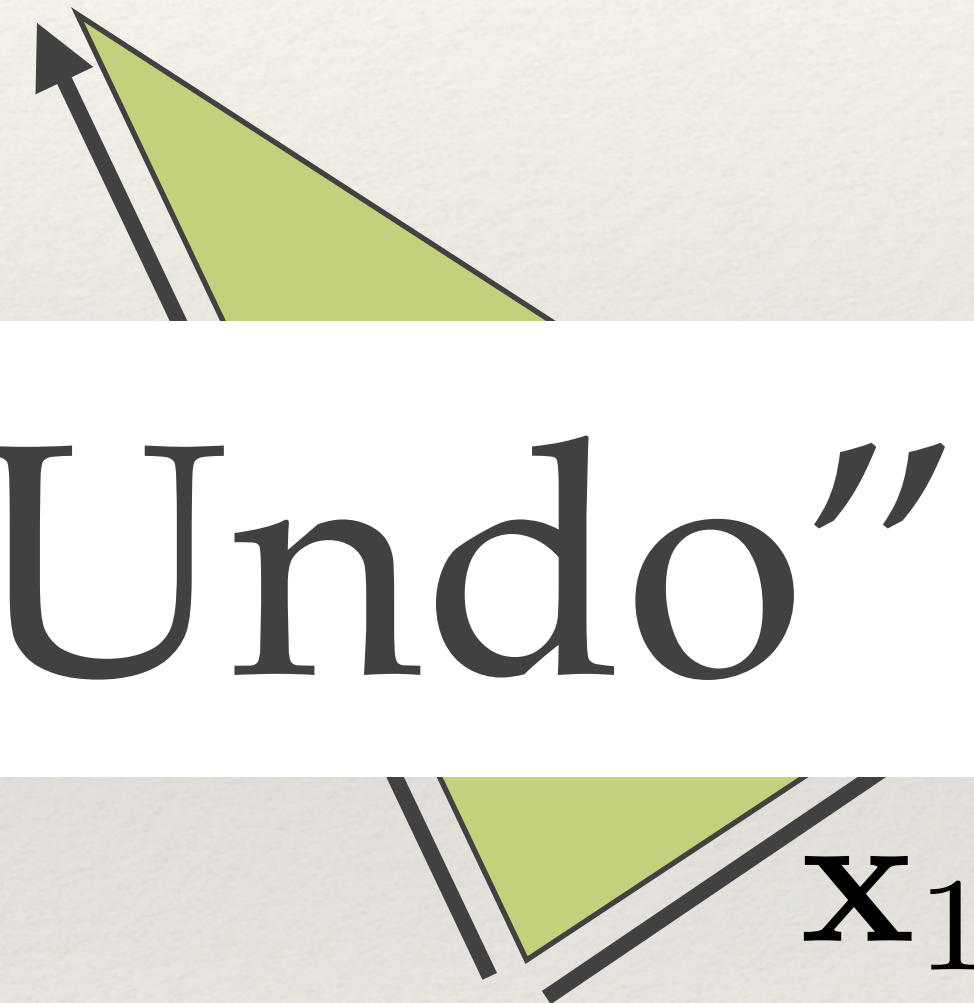
$$\mathbf{F} = \mathbf{X} \beta$$

Finite Elements

Rest



Deformed



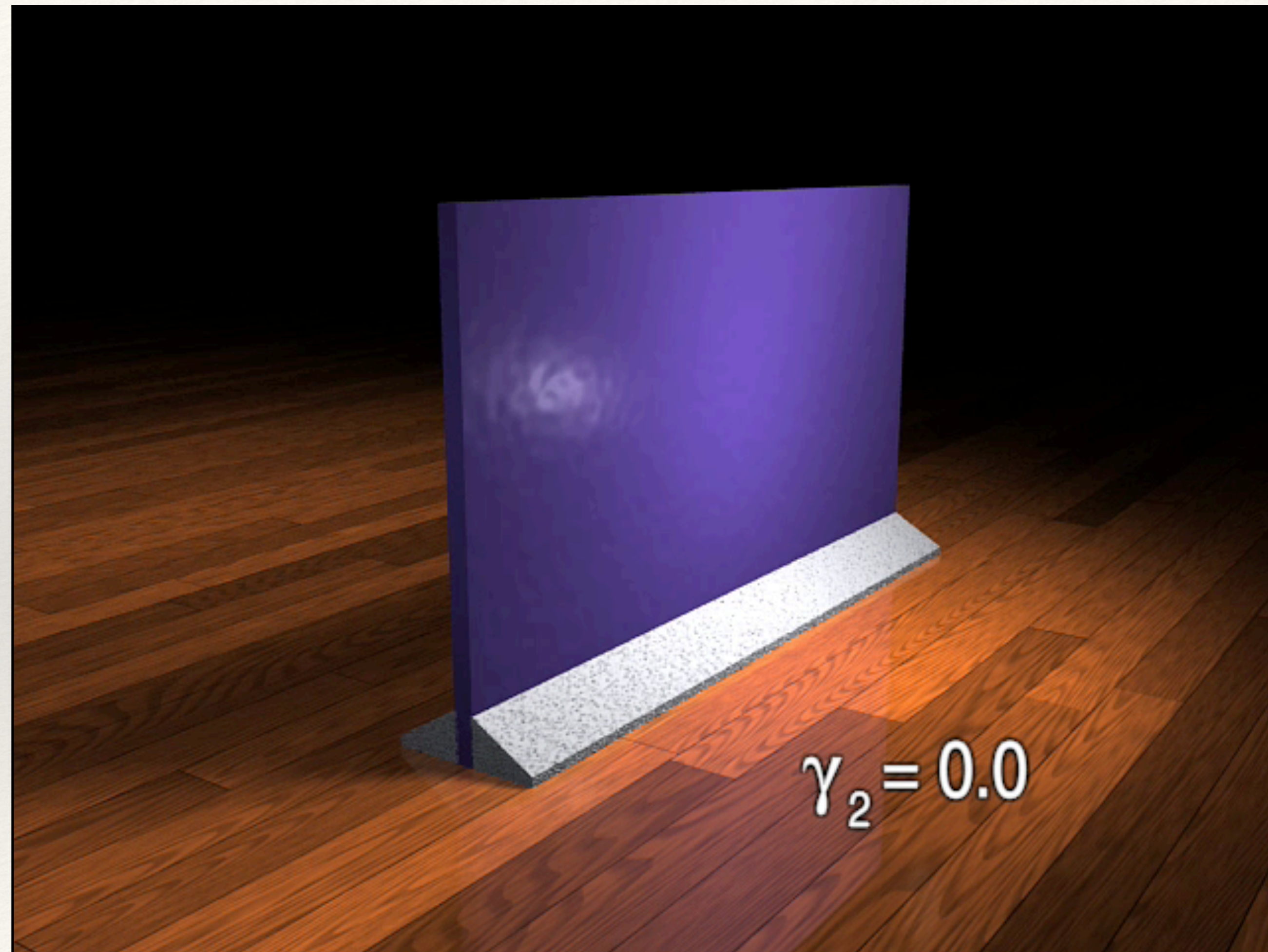
Elastic Forces “Undo” \mathbf{F}

$$\beta = (\mathbf{b}_1 \mathbf{b}_2)^{-1}$$

$$\mathbf{X} = (\mathbf{x}_1 \mathbf{x}_2)$$

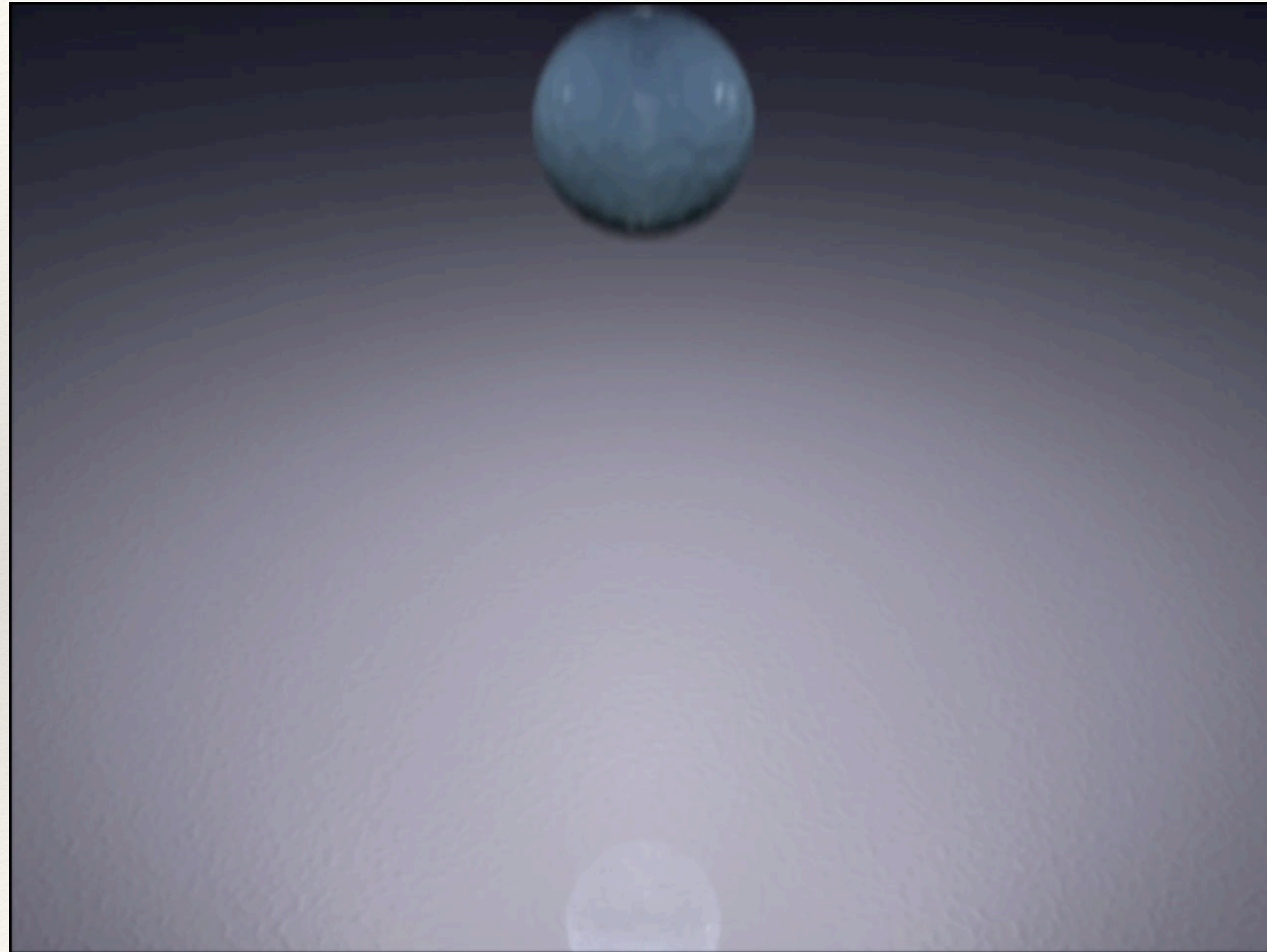
$$\mathbf{F} = \mathbf{X} \beta$$

Graphical Modeling and Animation of Ductile Fracture



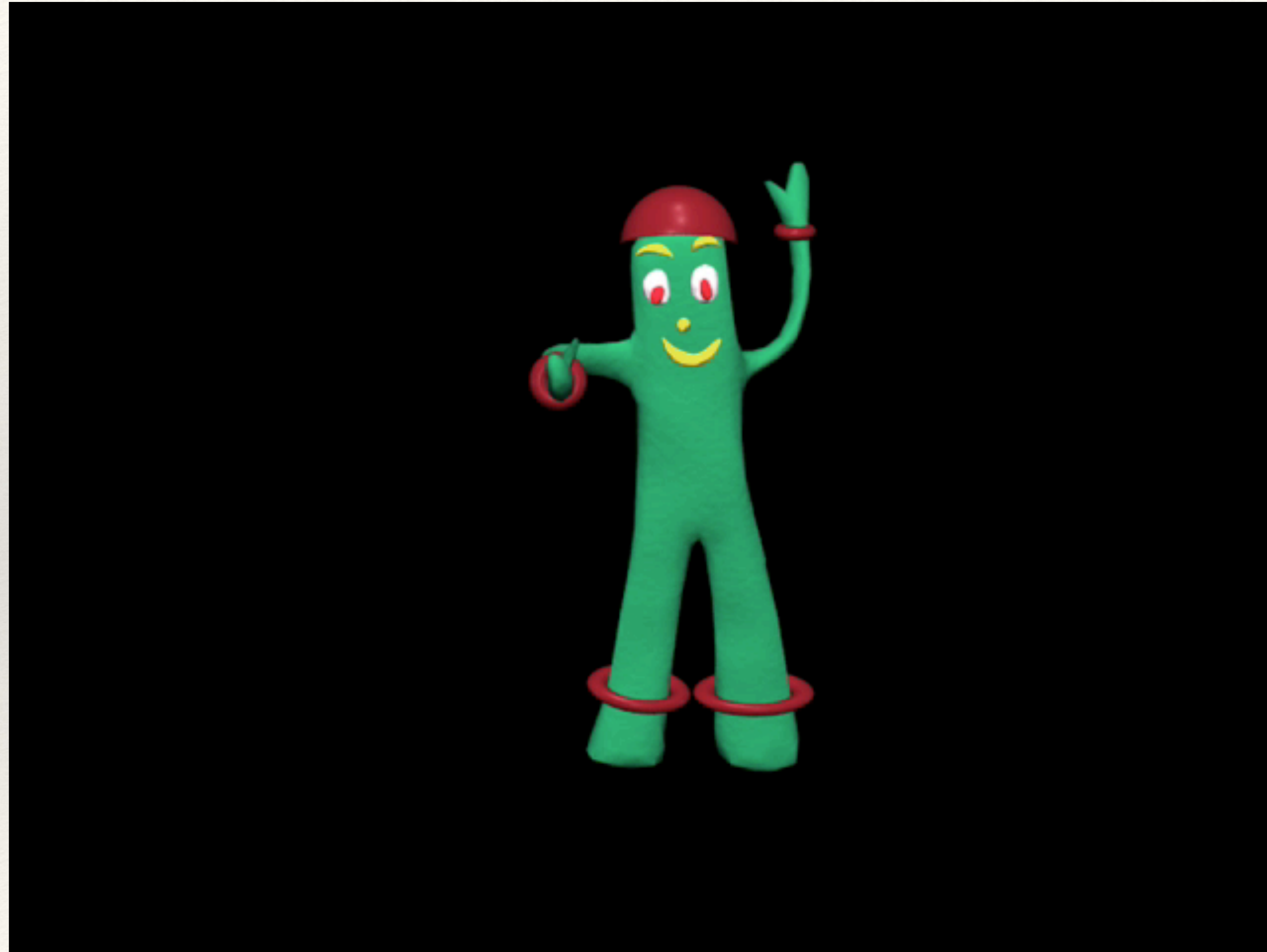
O'Brien, Bargteil & Hodgins [SIGGRAPH 2002]

Graphical Modeling and Animation of Ductile Fracture



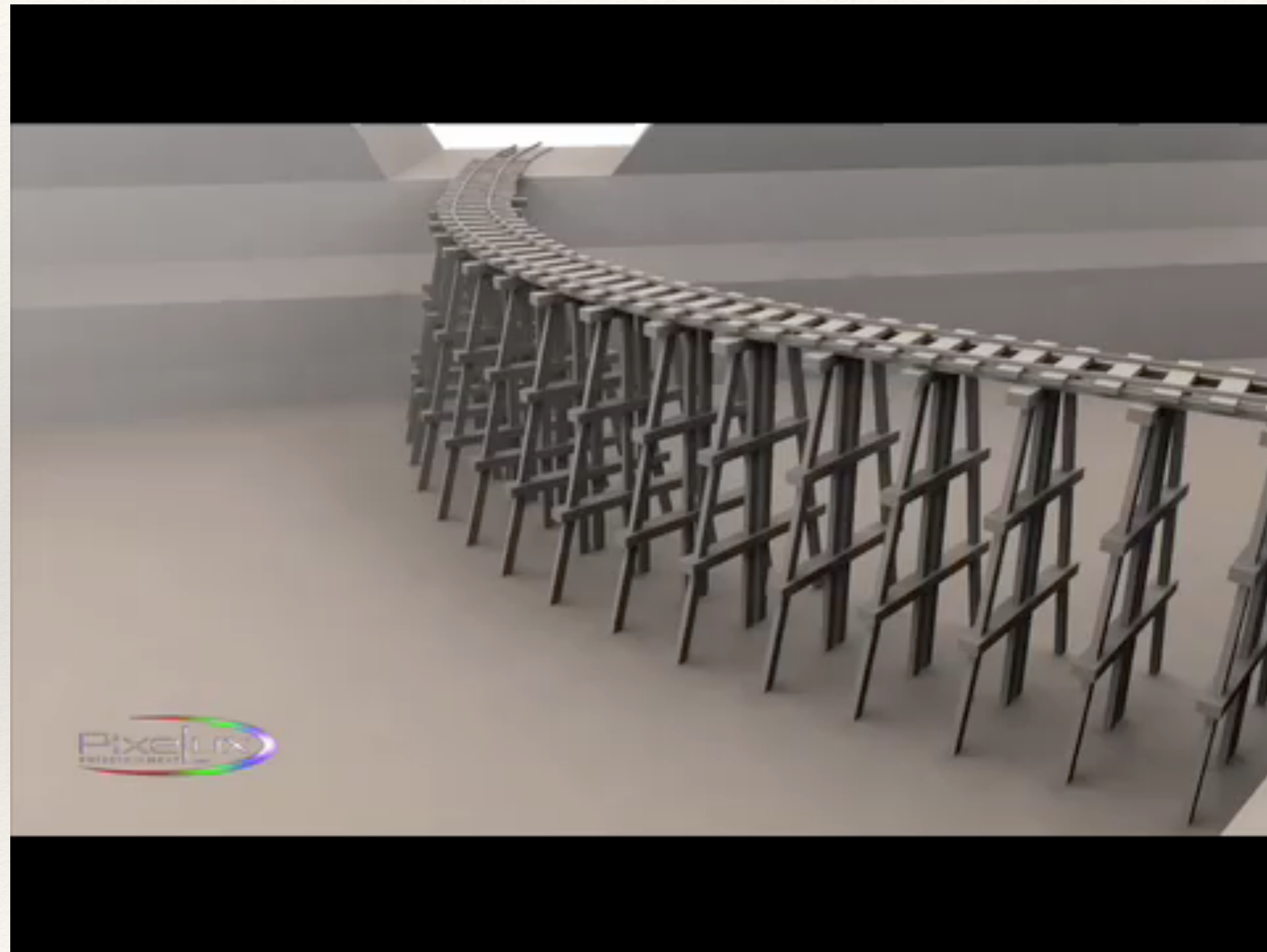
O'Brien, Bargteil & Hodgins [SIGGRAPH 2002]

Graphical Modeling and Animation of Ductile Fracture



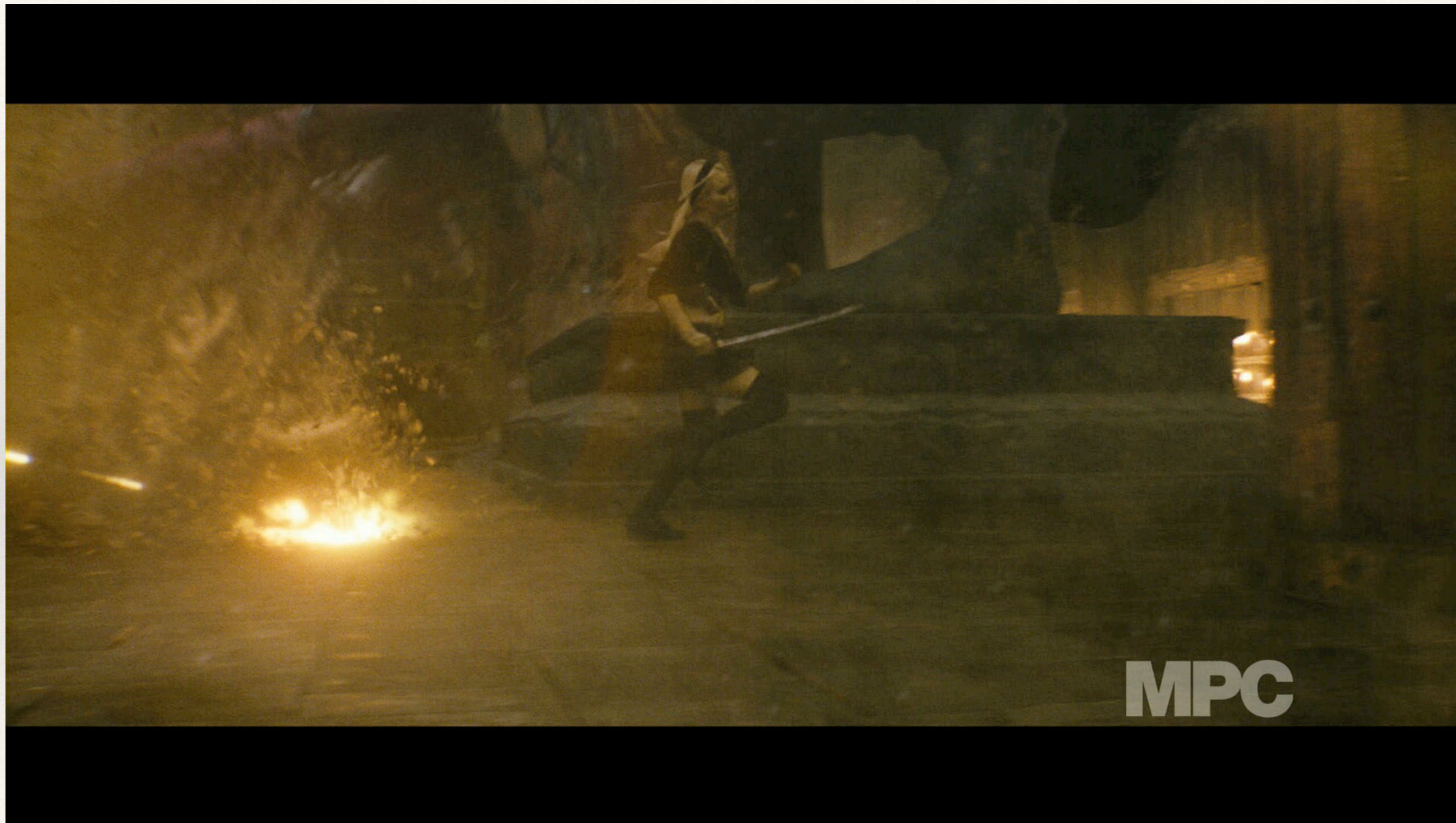
O'Brien, Bargteil & Hodgins [SIGGRAPH 2002]

Digital Molecular Matter



Parker & O'Brien [SCA 2009]

Moving Picture Company's *Kali*



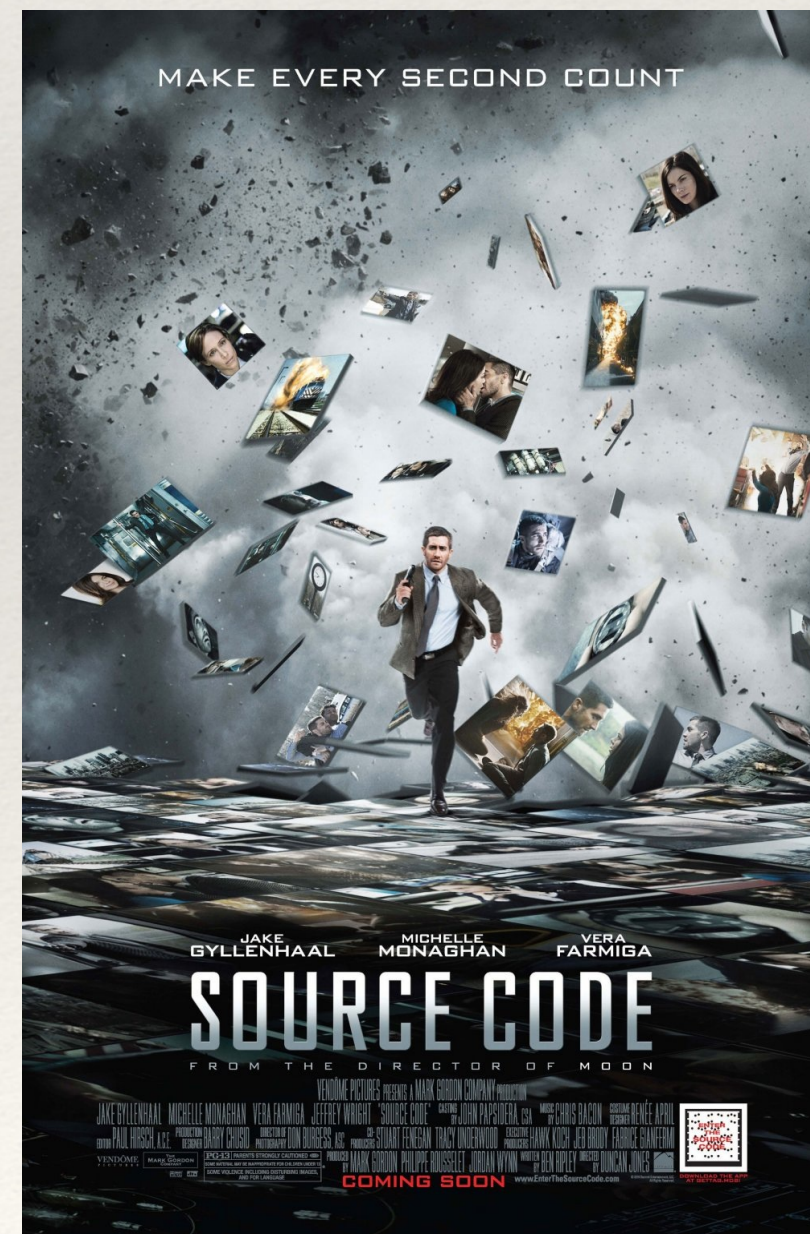
Cole [SIGGRAPH 2011 Talk]

2010

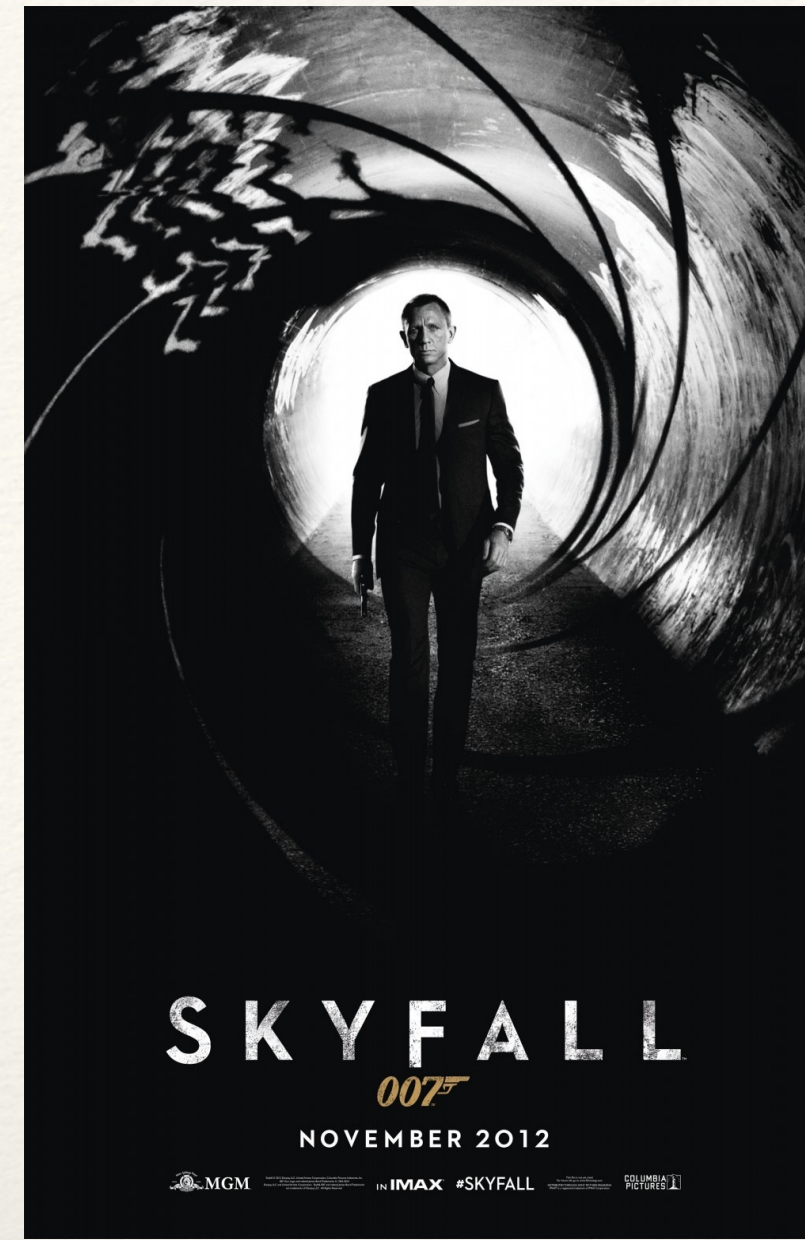
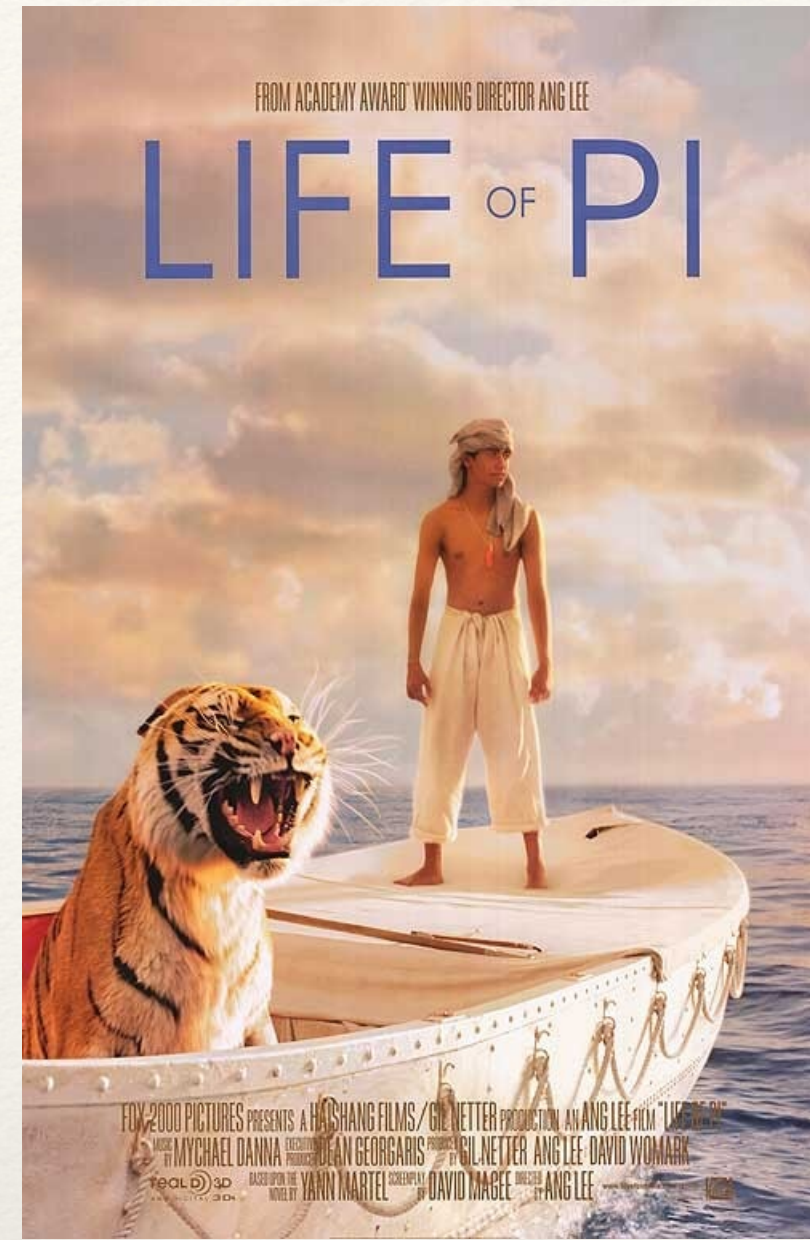


MPC Films using Kali / DMM

2011



2012



2013



2014



2015 Technical Achievement Award



The State of the Art

- ❖ special effects are almost universally achieved through computer graphics
- ❖ almost all films contain some computer animation
- ❖ an artist can create almost any effect they can imagine

Groundhog Day (1993)



Edge of Tomorrow (2014)



The Future

more, better tools

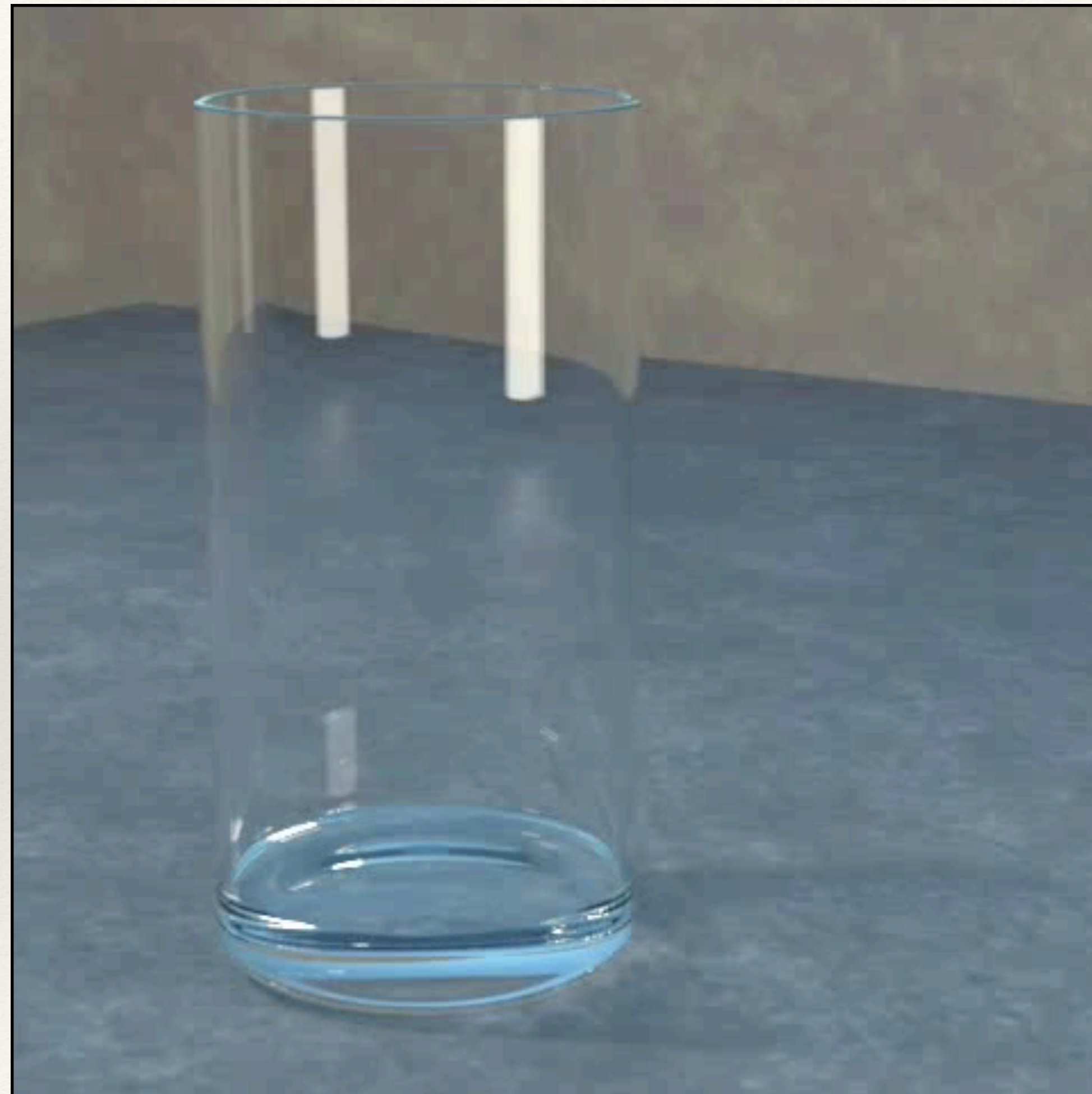
interactive animation

virtual / augmented / mixed reality

content creation

*A Specialized Tool for
Large-scale Splashing Liquids*

Small Scale Liquids



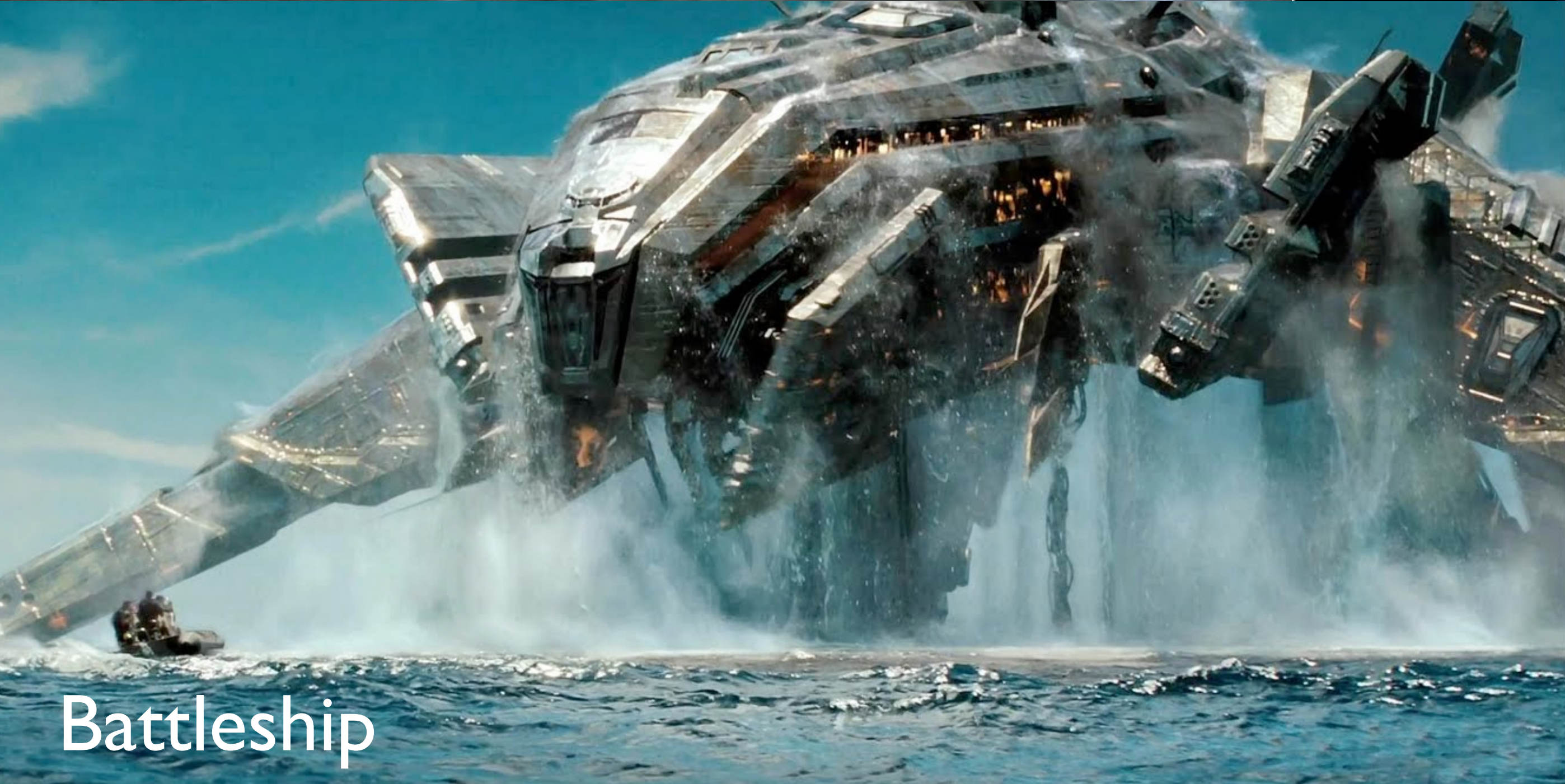
Enright, Marschner & Fedkiw [SIGGRAPH 2002]



Deep Impact



2012



Battleship



The Day After Tomorrow

like a good physicist we observe the
phenomena we wish to model





An Observation About Splashes

surface tension causes liquids to pinch off into droplets, which then mix freely with air and...

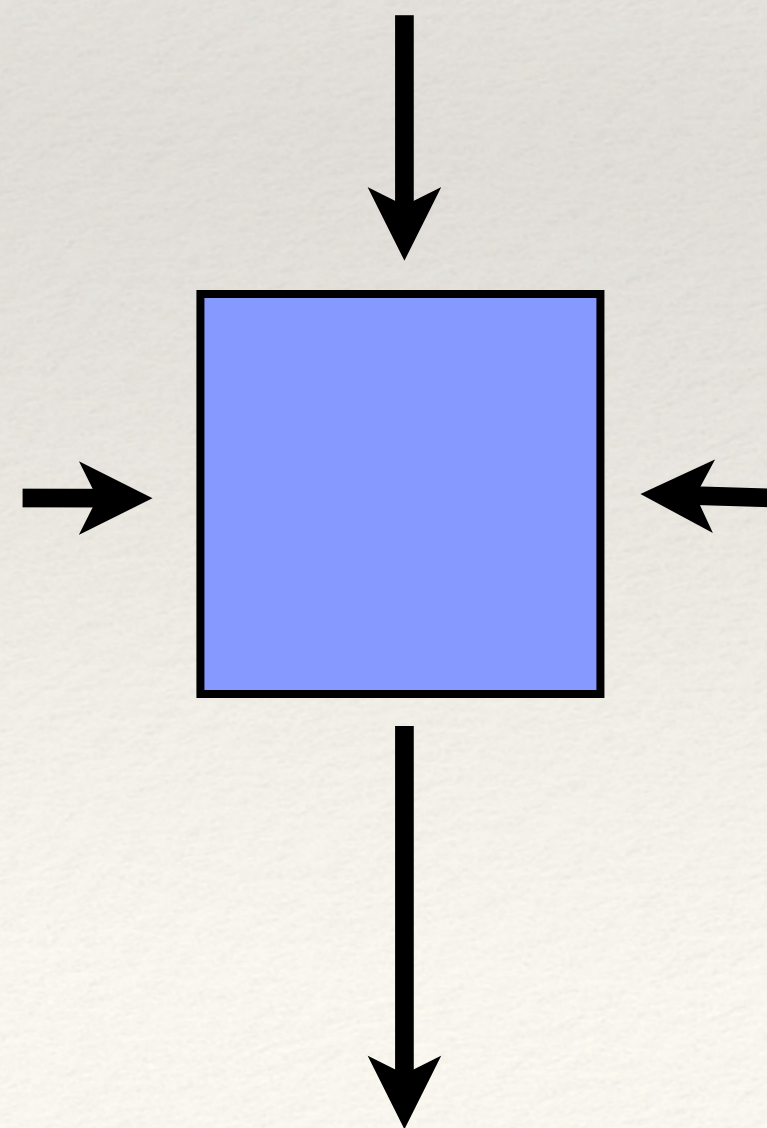
...the liquid *appears* to expand

A New Model

Bilateral

Incompressibility

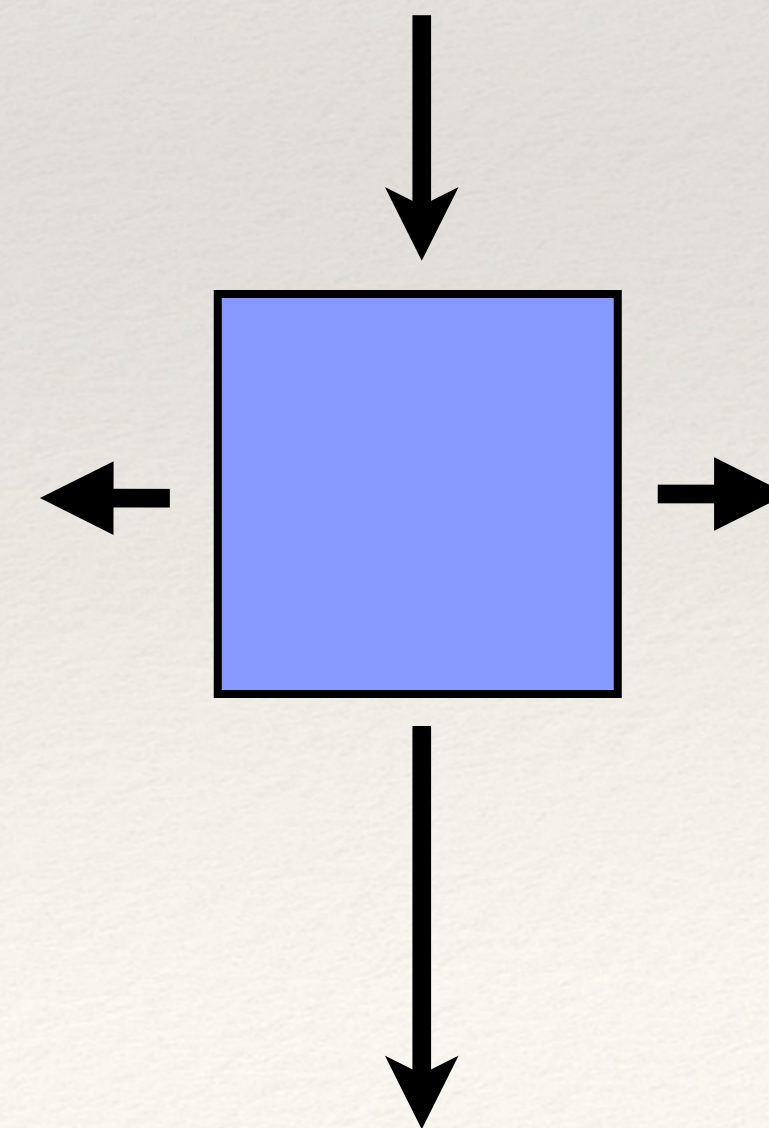
fluid in == fluid out



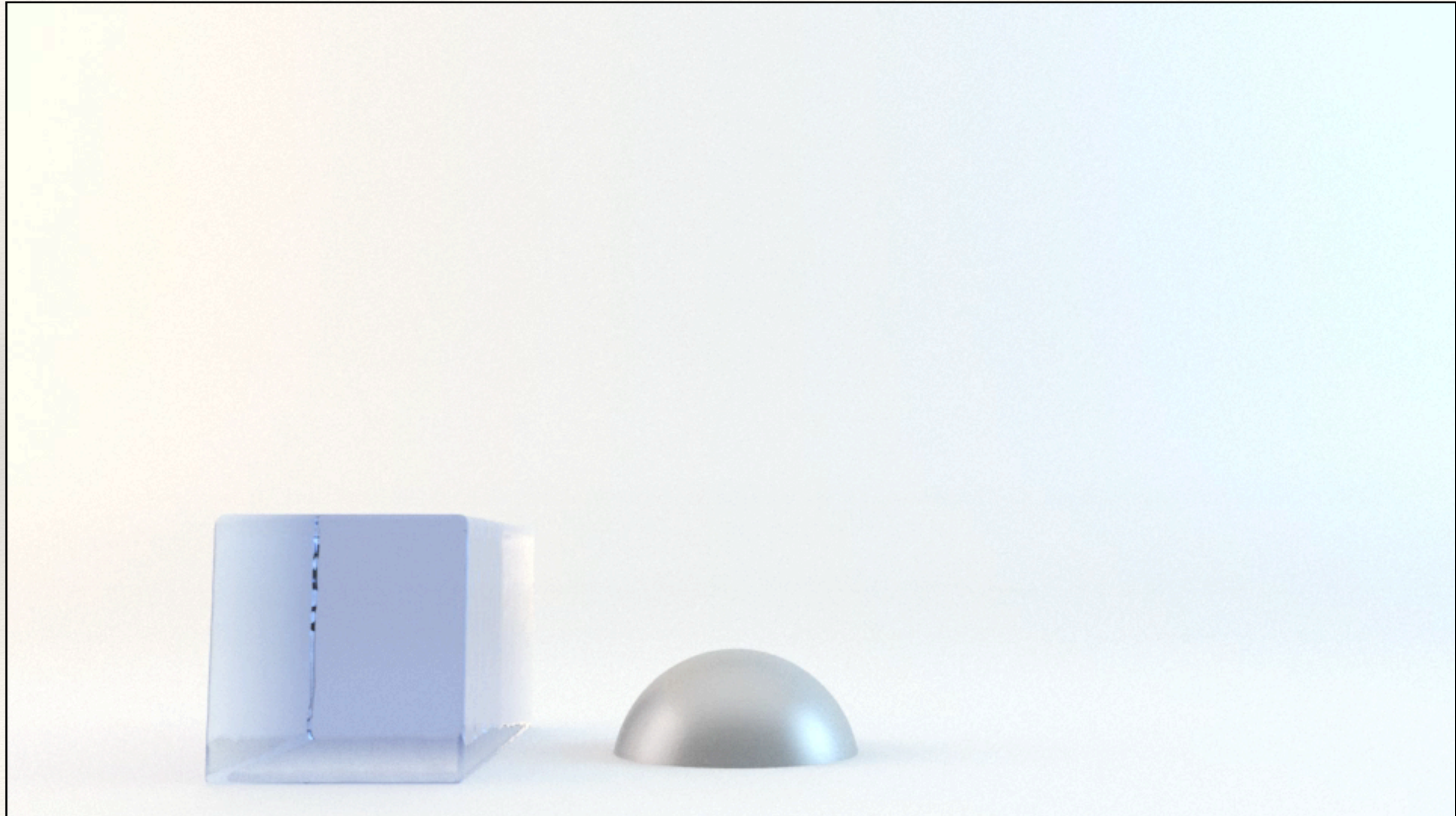
Unilateral

Incompressibility

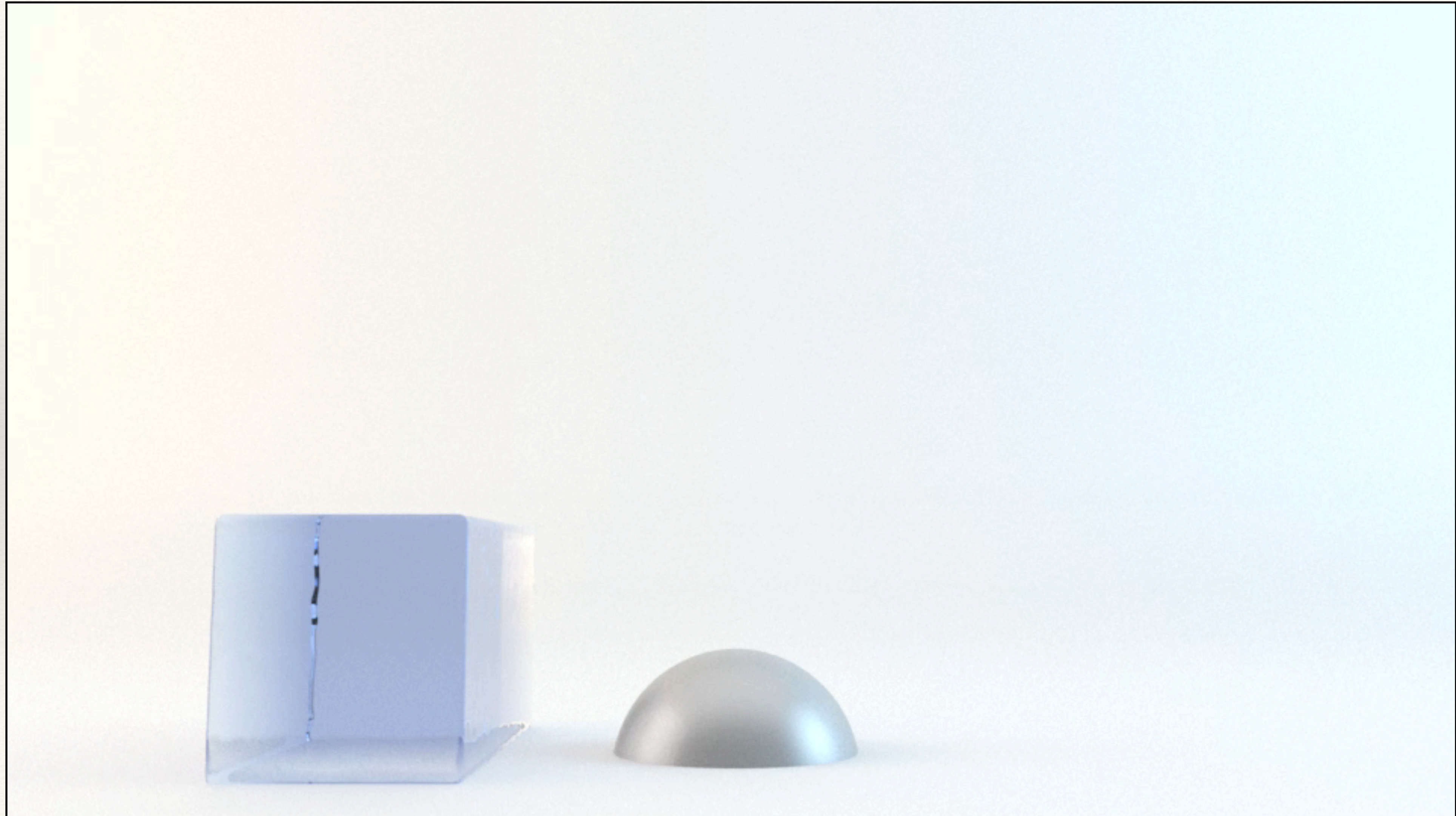
fluid in <= fluid out



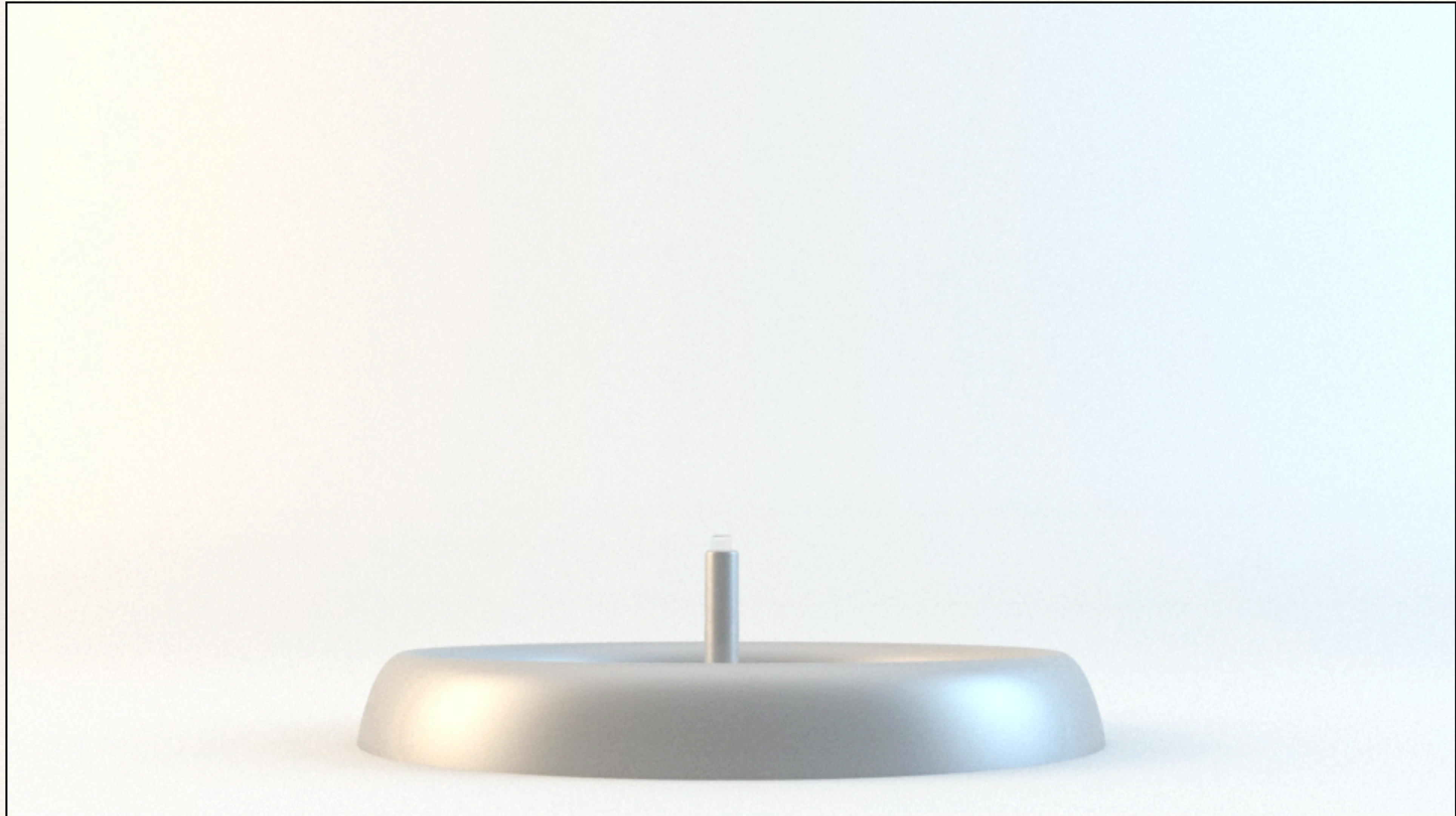
Traditional Fluid Simulation: Incompressible



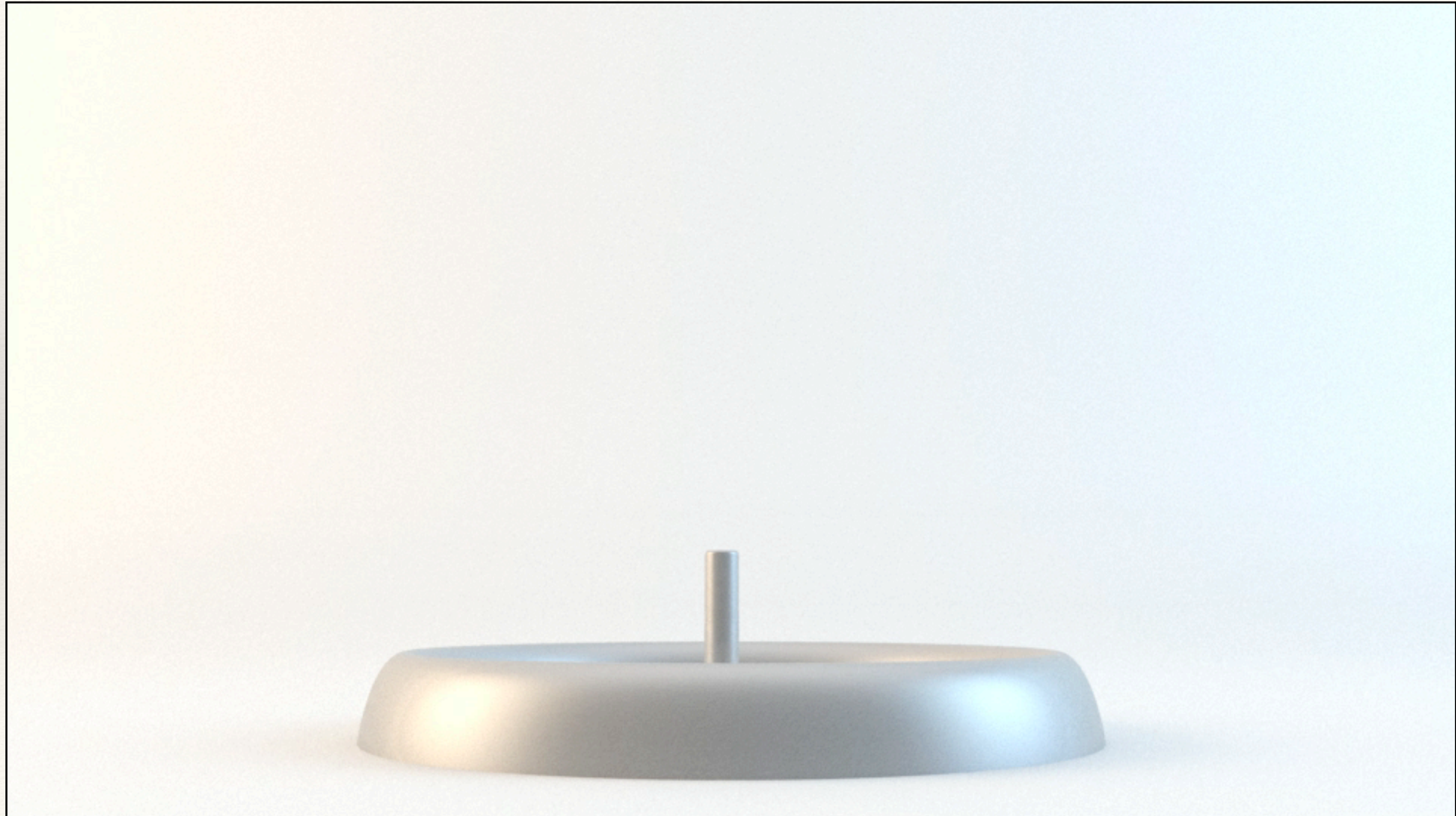
New Model: Unilateral Incompressibility



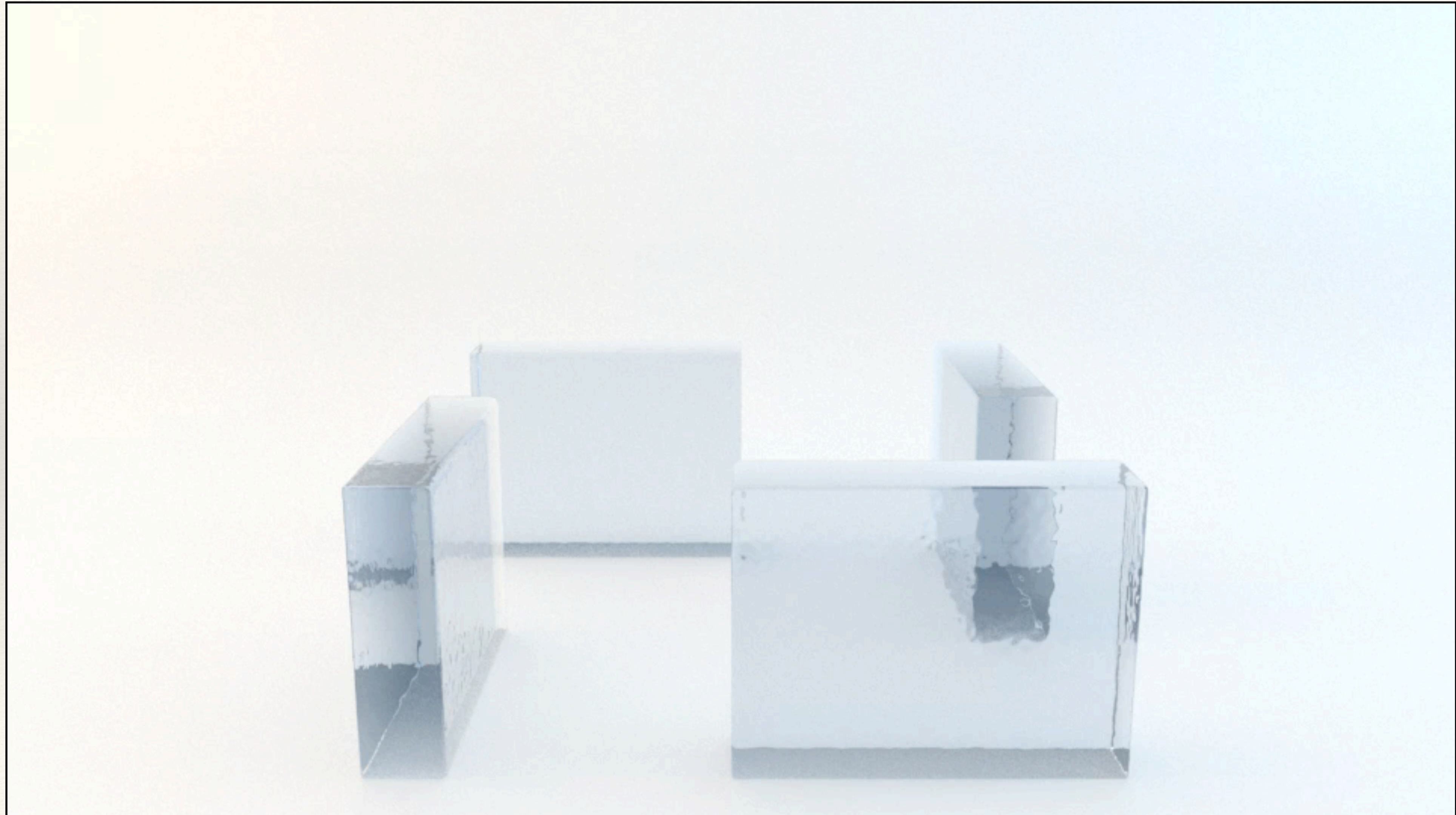
Incompressible Fountain



Unilaterally Incompressible Fountain

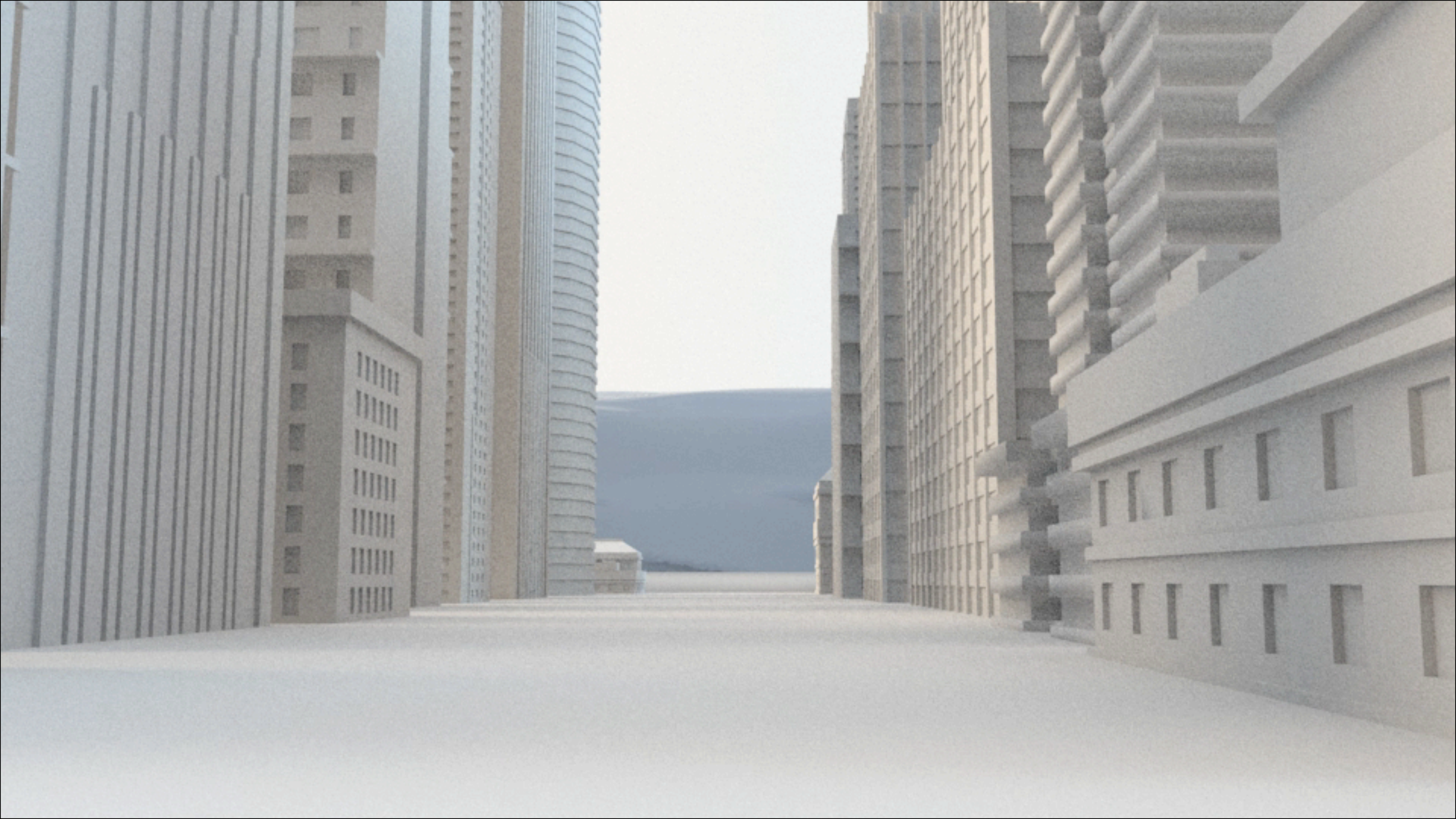


Four Dams



Flooded Terrain

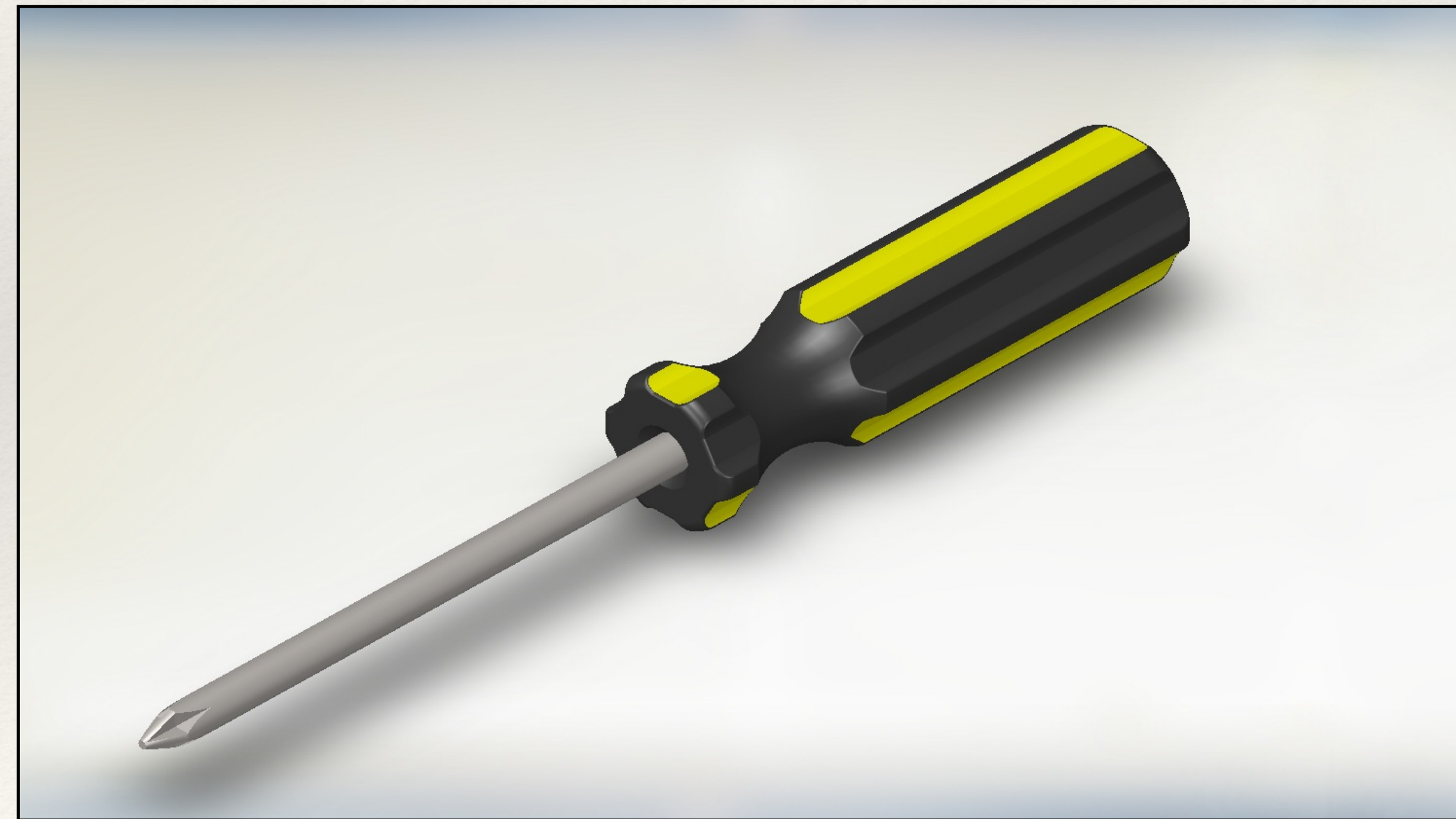
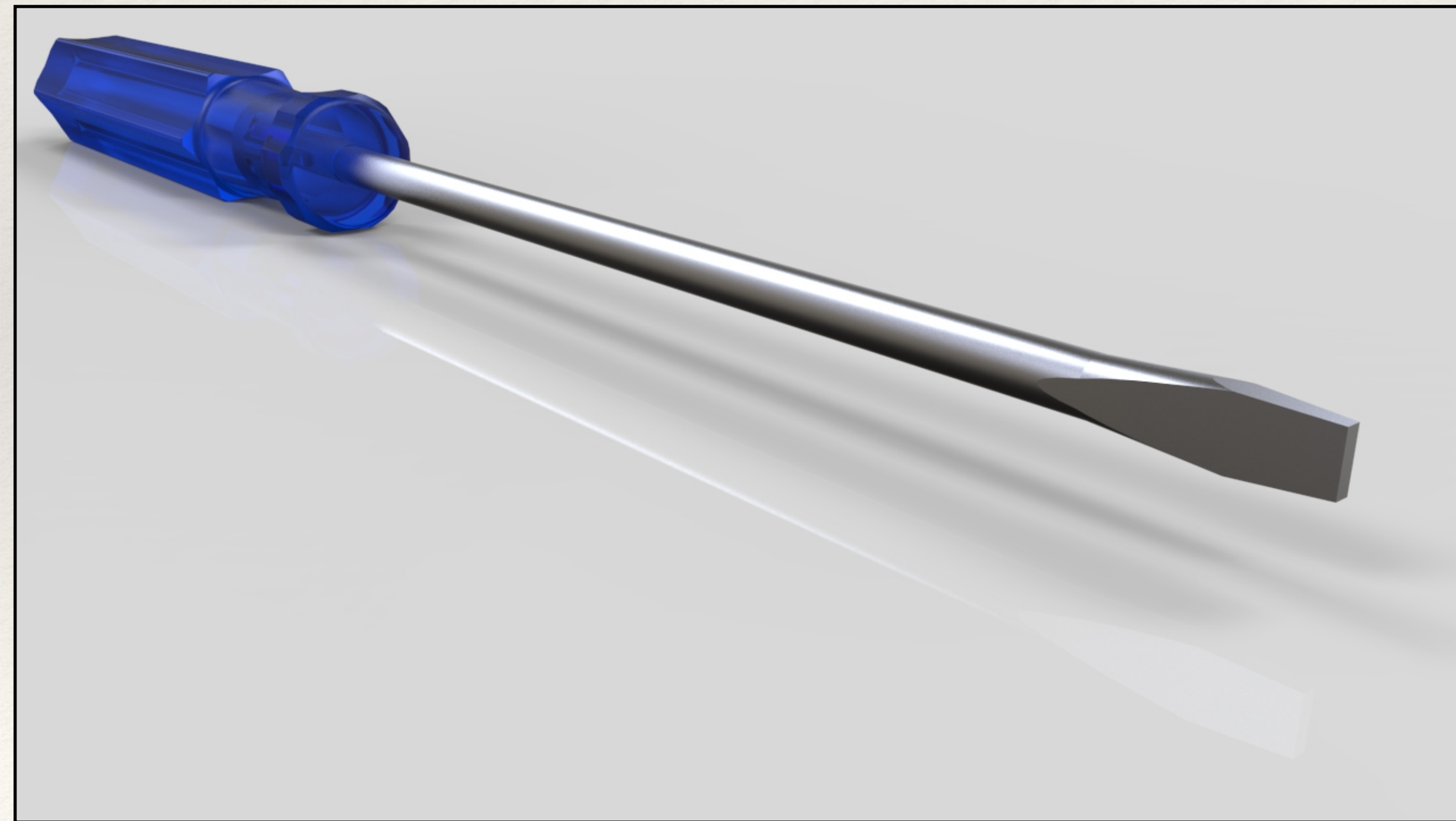




Flathead & Philips

bilateral
incompressibility

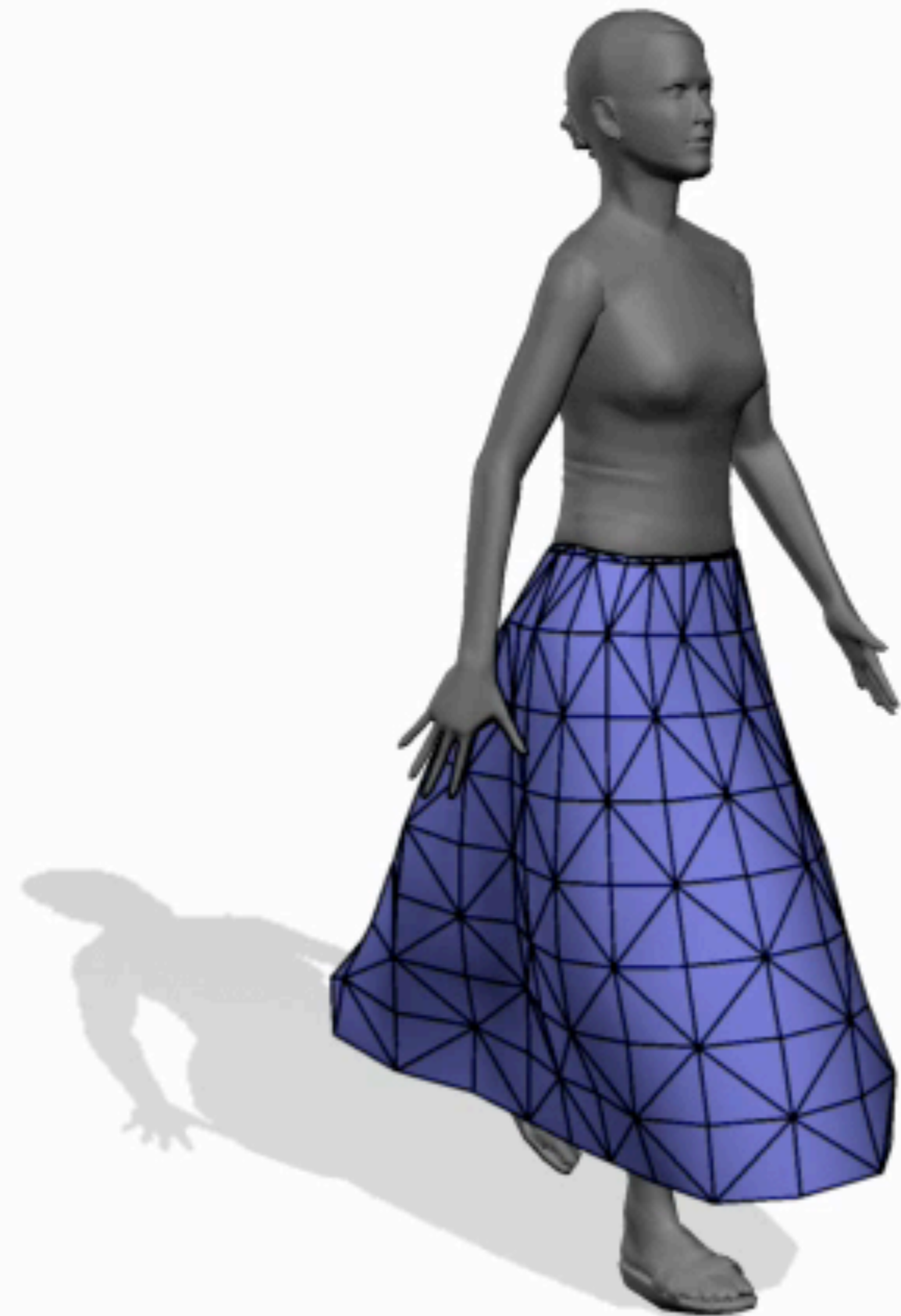
unilateral
incompressibility



Beyond Special Effects: Interactive Animation

Learning an Upsampling Operator

Input
(Coarse Simulation)



Output
(Upsampled)



Learning an Upsampling Operator

Regularization on Training Data



None

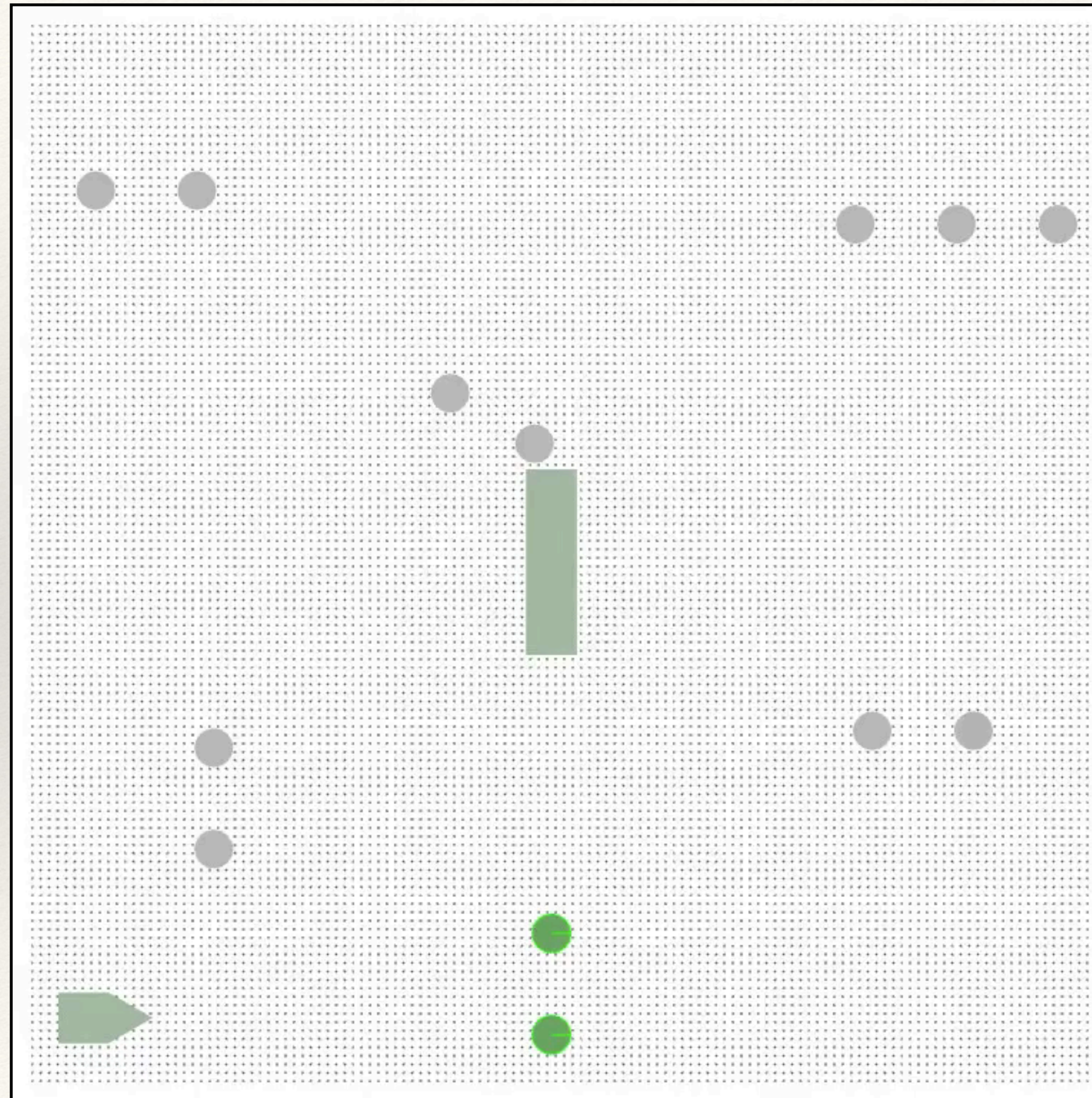


Just Right

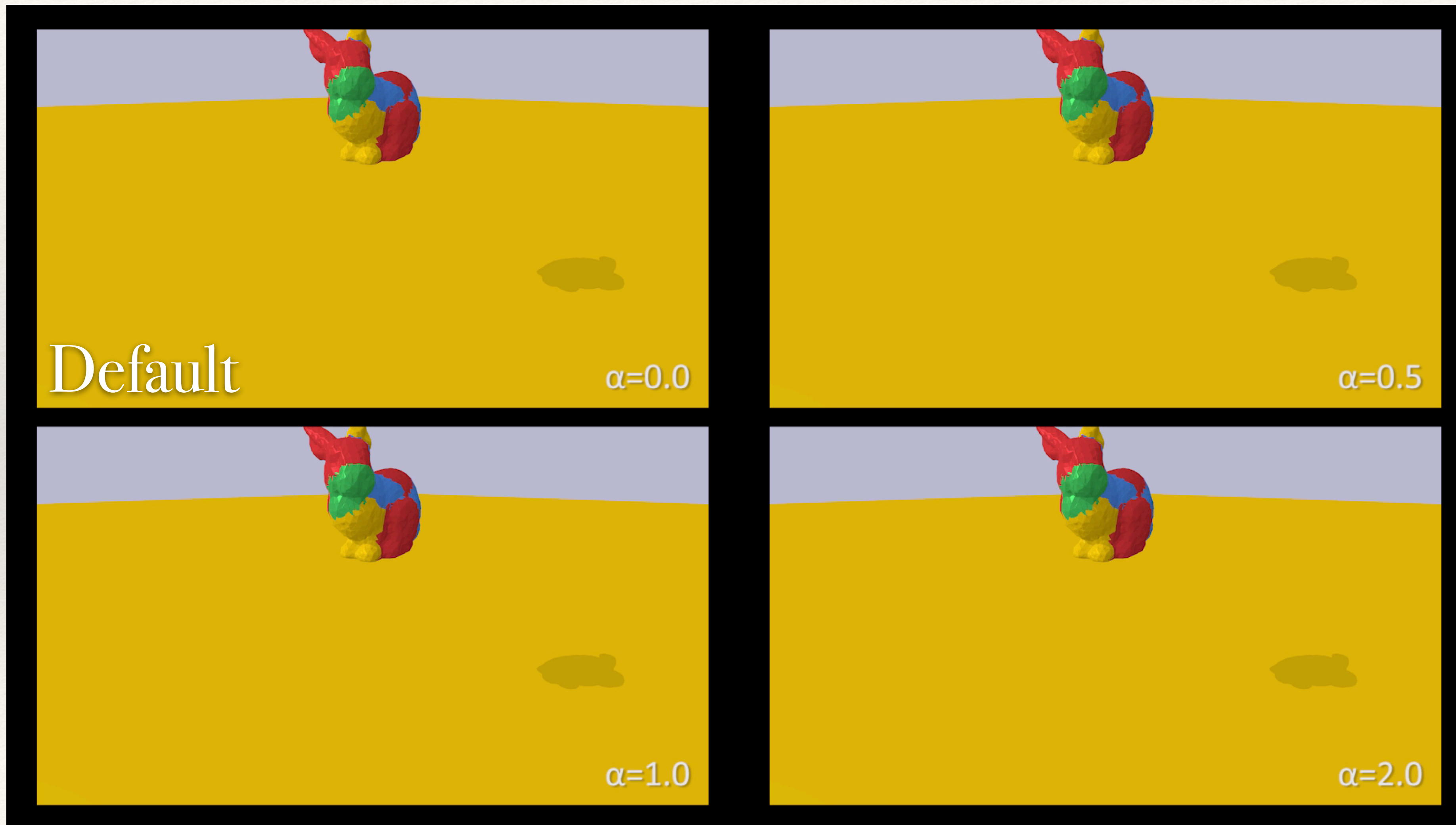


Too High

Model Reduced Fluids



Energizing Fracture



take away:

making offline methods faster is not enough,
interactive animation requires new techniques



Virtual / Augmented / Mixed

Reality is Going to Drive

Computer Animation

Content Creation

(the elephant in the room)

let's look at physics-based animation /
simulation

- (1) simulation is a *tool* for artistic expression
- (2) good tools are easy to use

are physical simulations easy to use?

no.

Physics is like a cat...



... it does what it wants

Artists want dogs



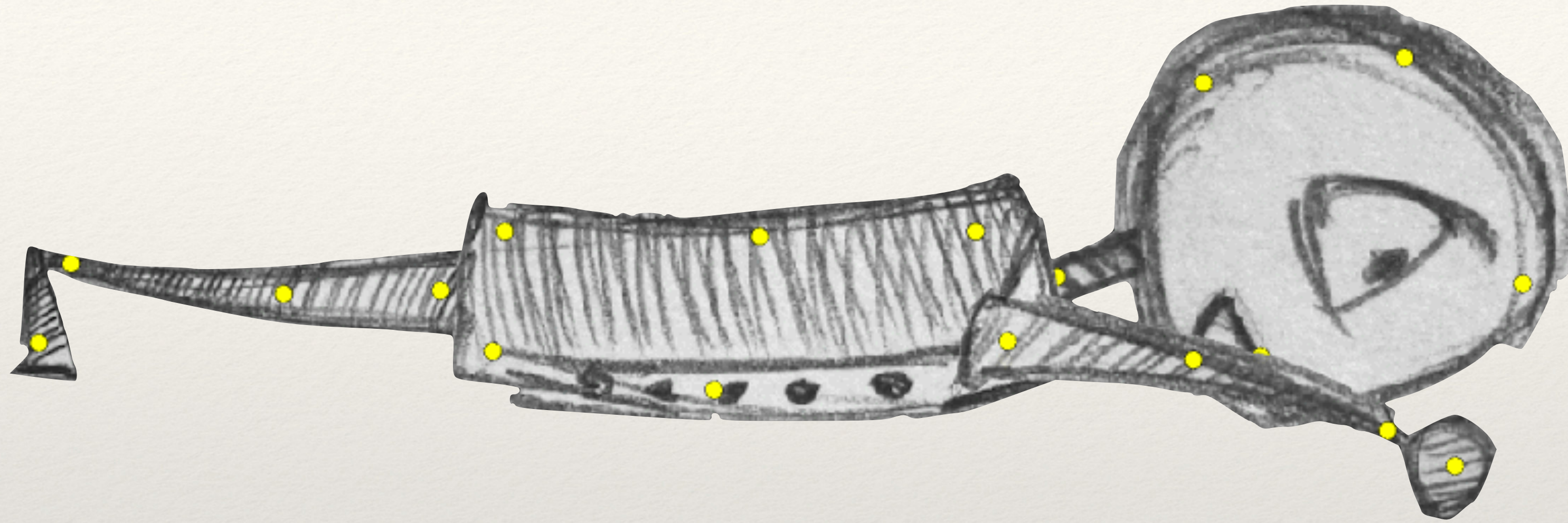
Dynamic Sprites

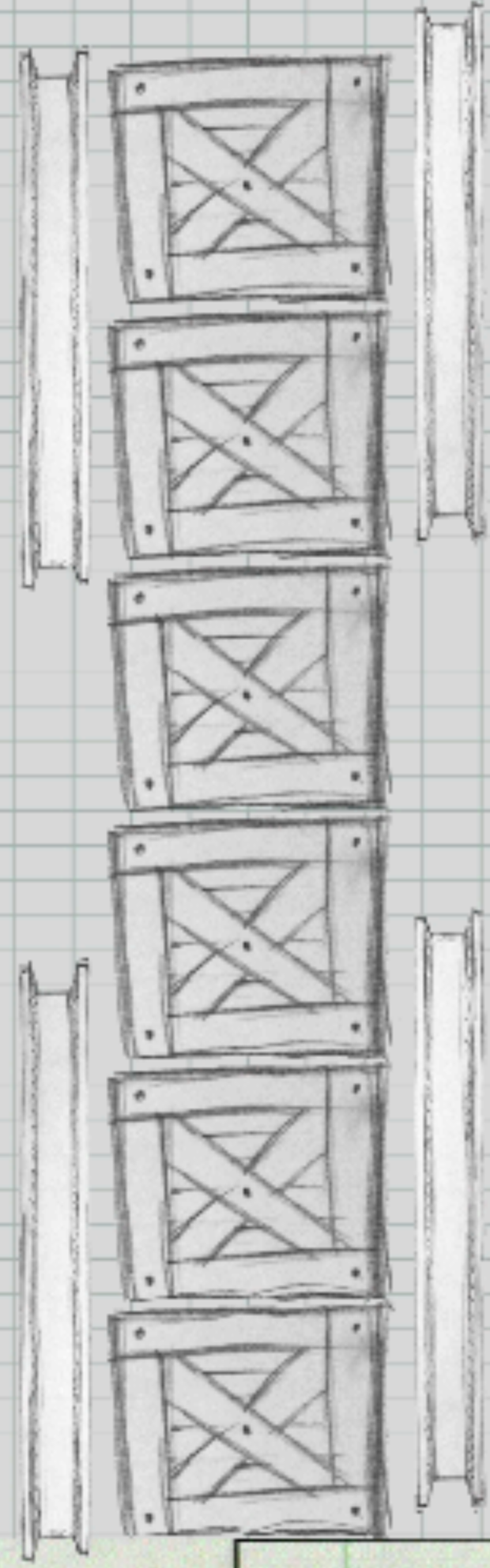
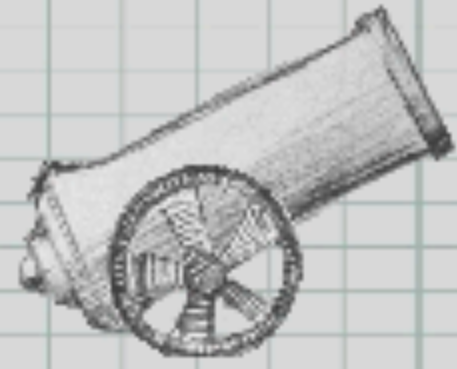
bring images to life by

letting artists define the behavior and

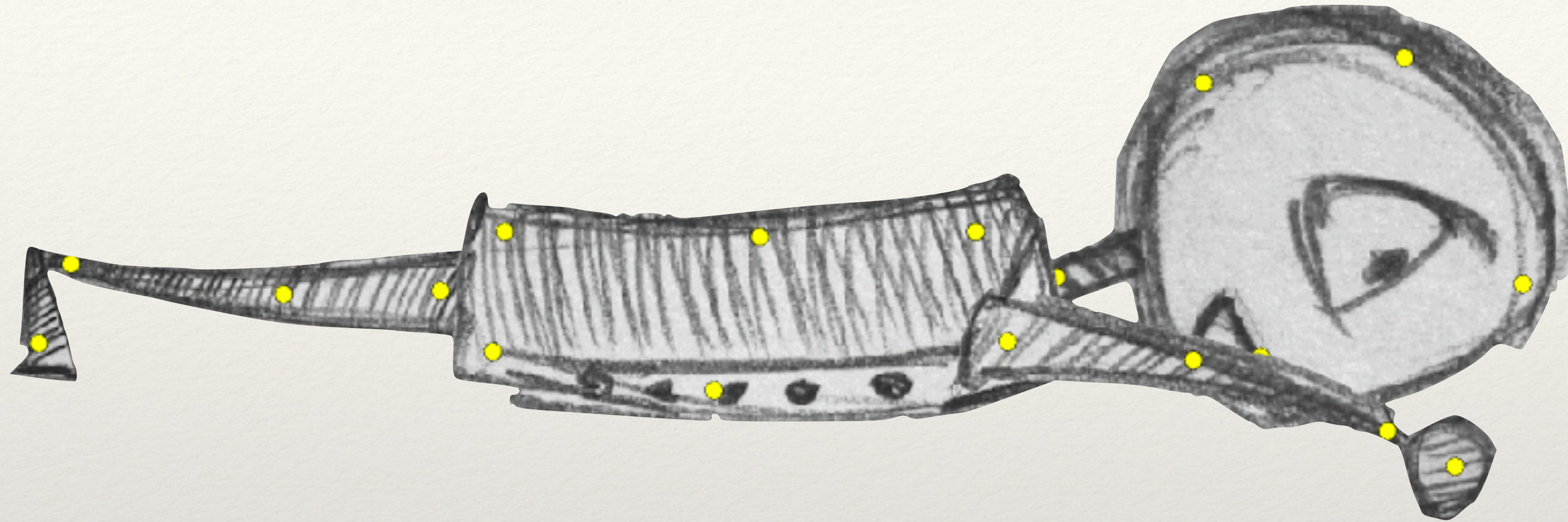
letting physics handle interaction & timing

Step 1: Draw a “Stuntman”

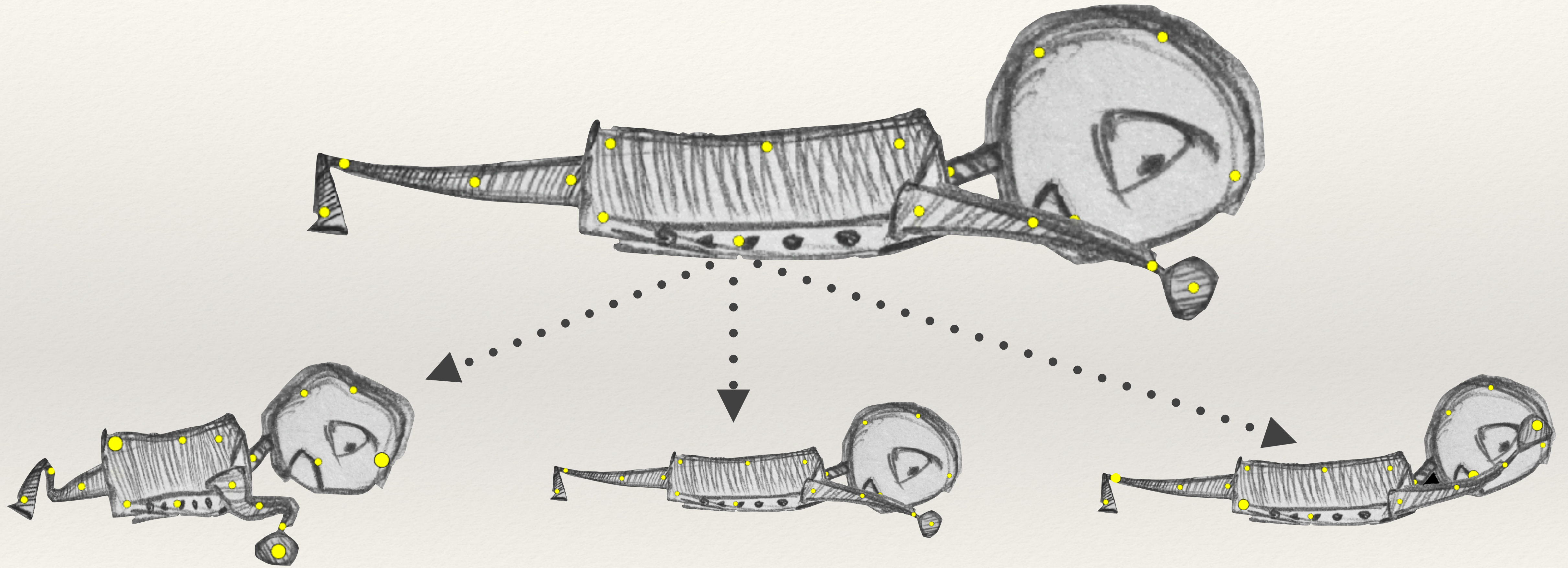




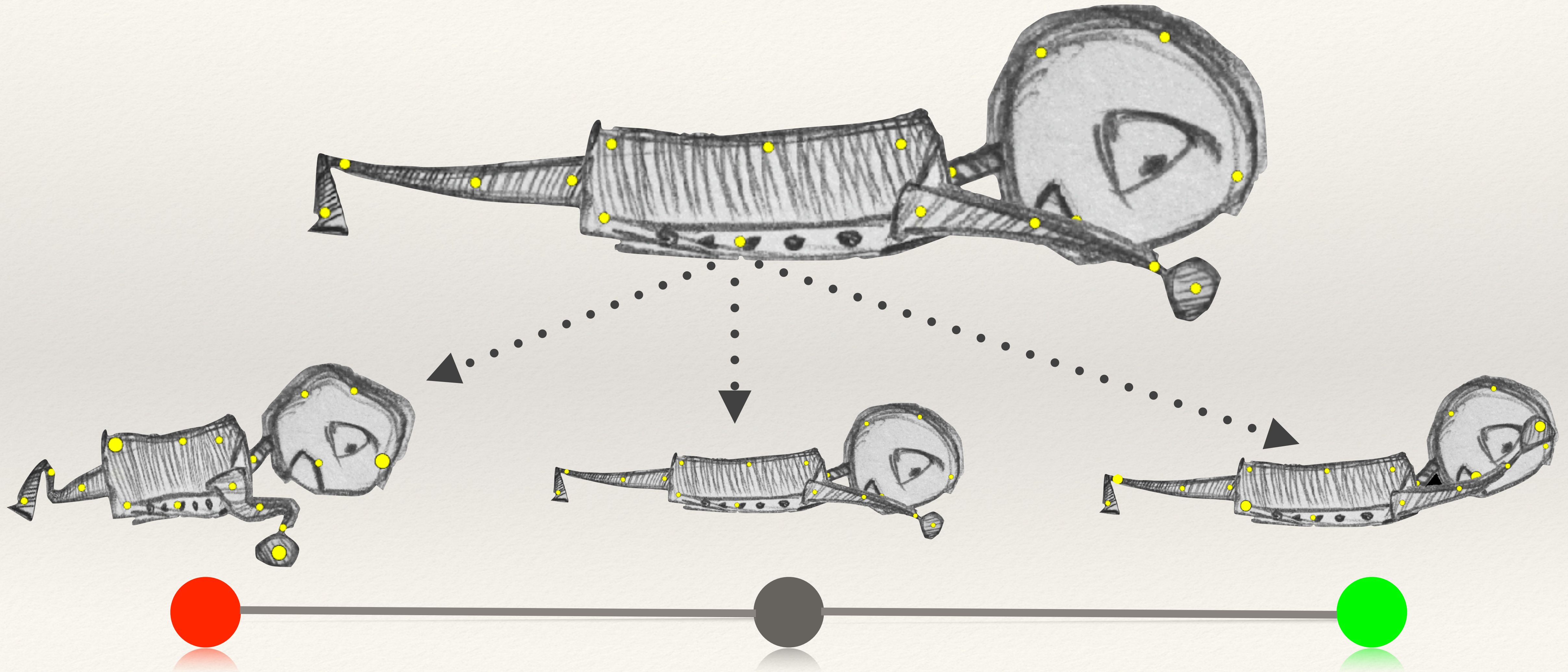
Step 2: “Rig” Drawing

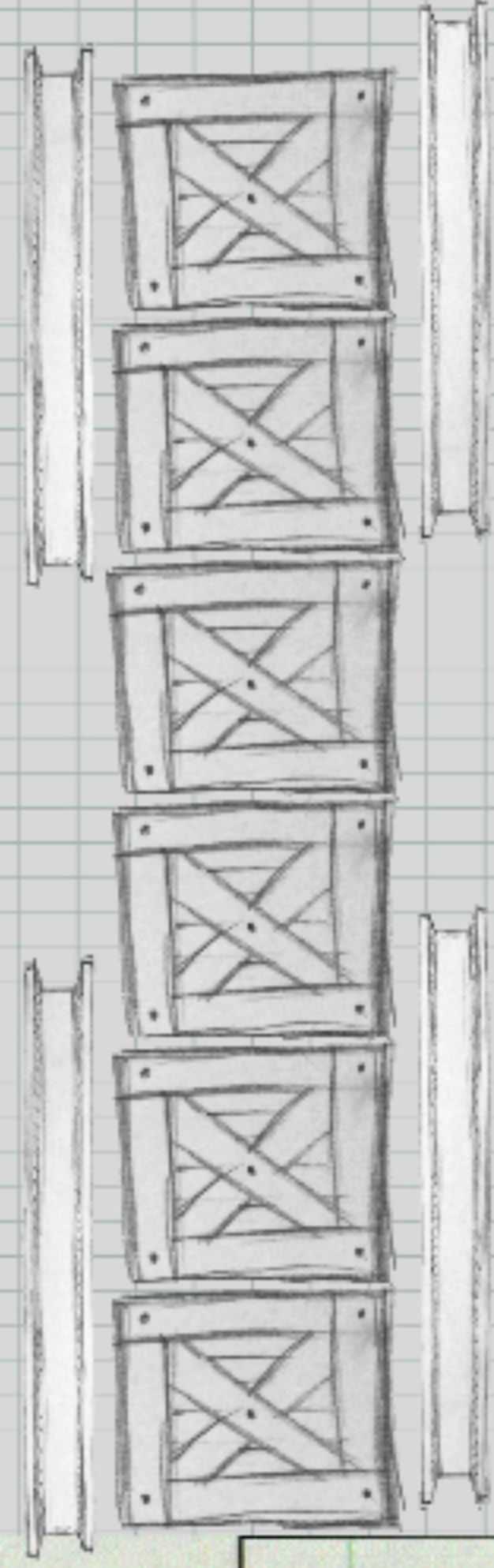
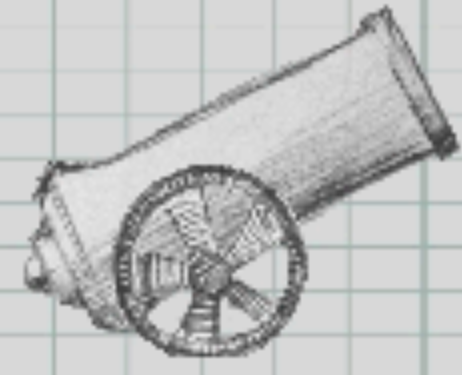


Step 3: Deform Drawing

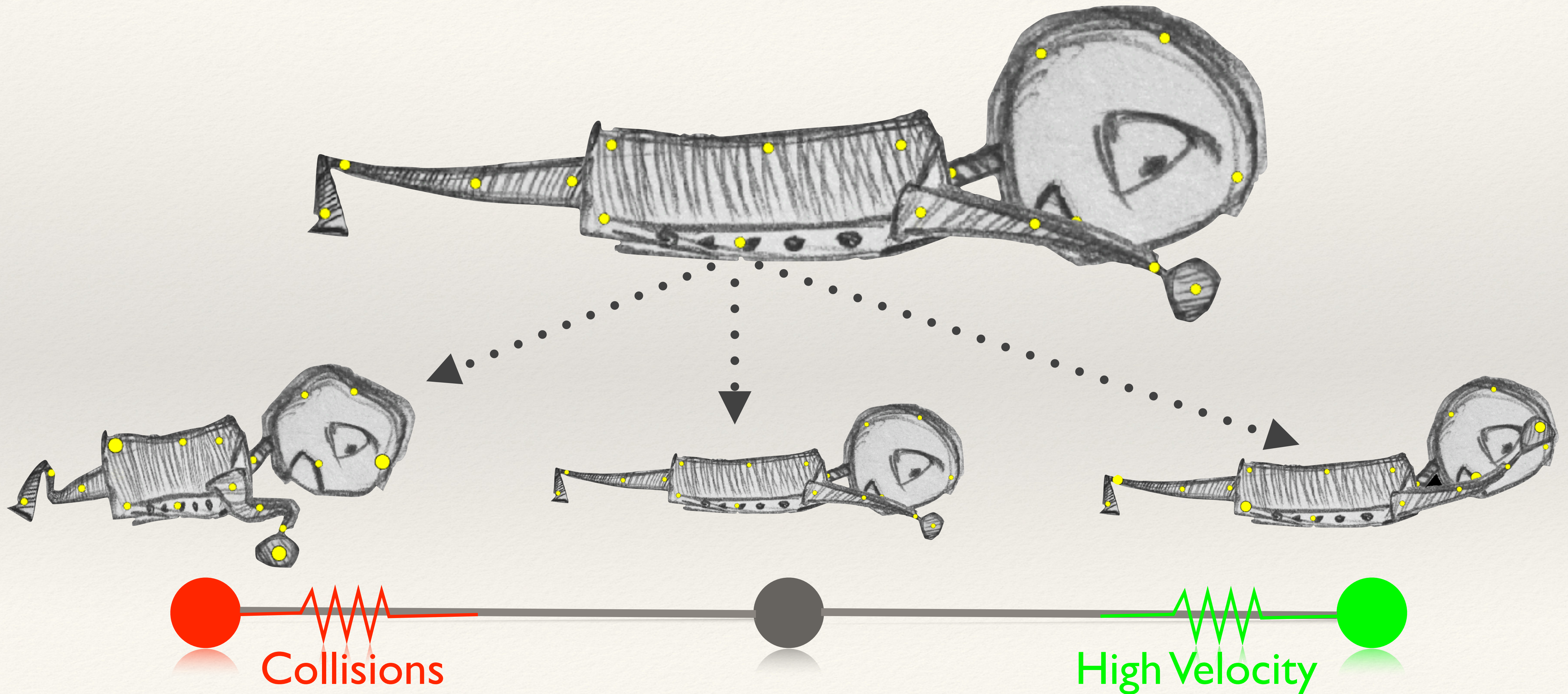


Step 4: Create “Example Manifold”



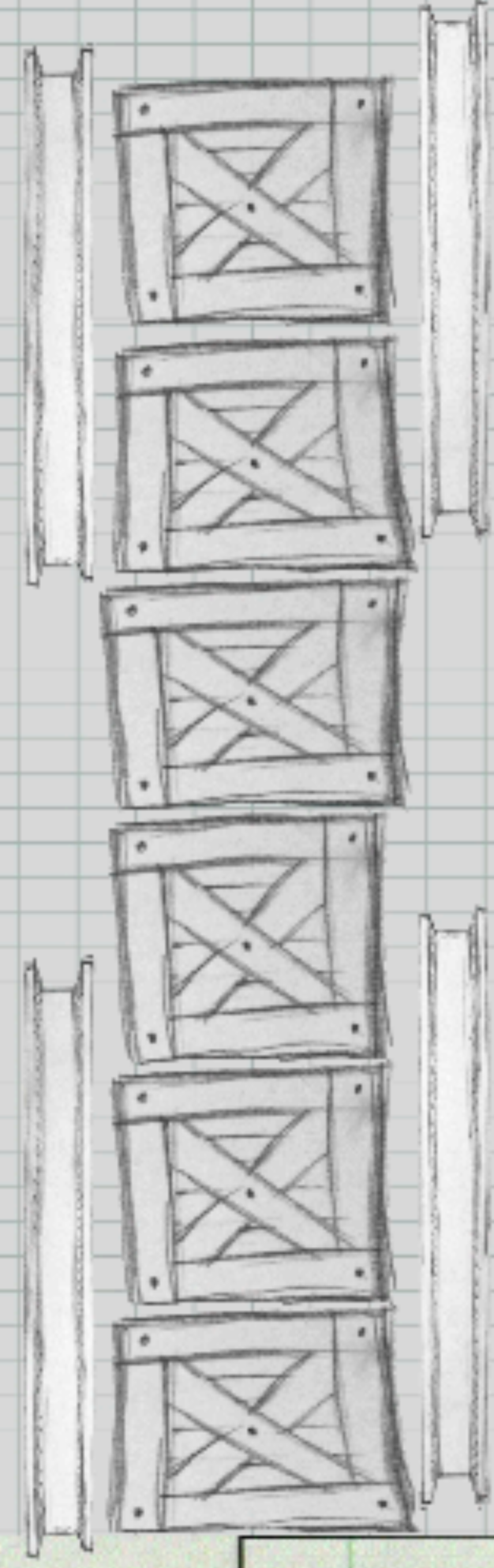
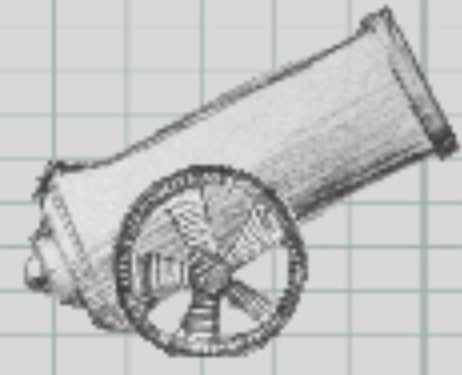


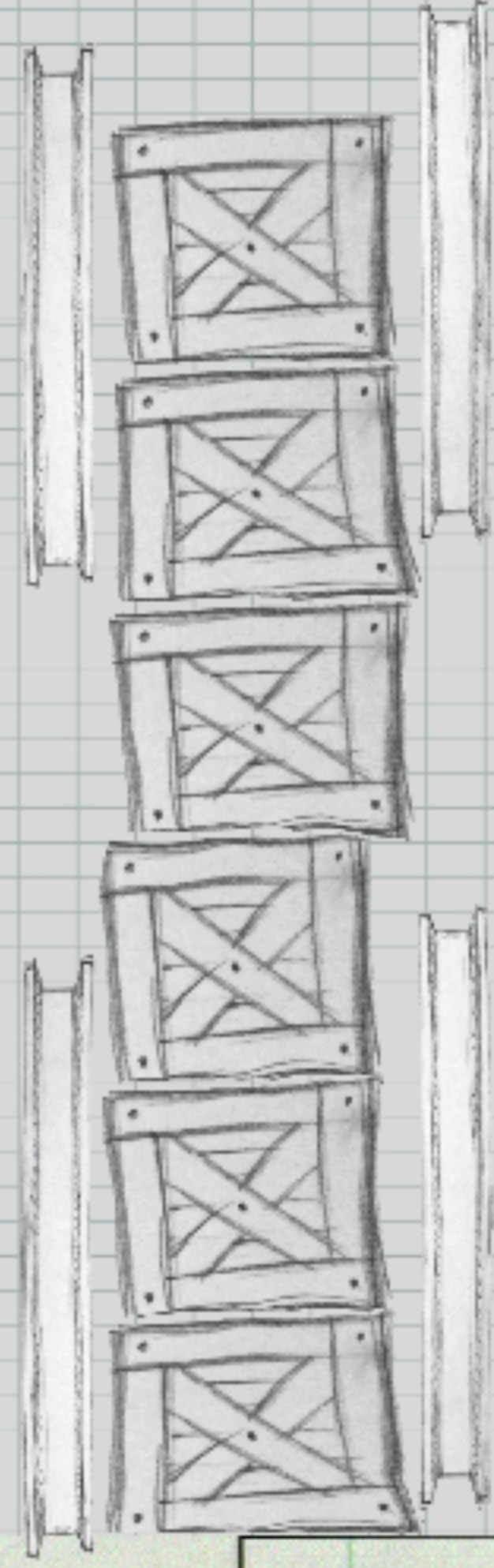
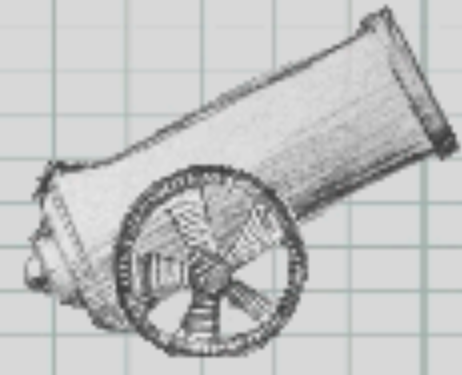
Step 5: Define Navigation in the Manifold

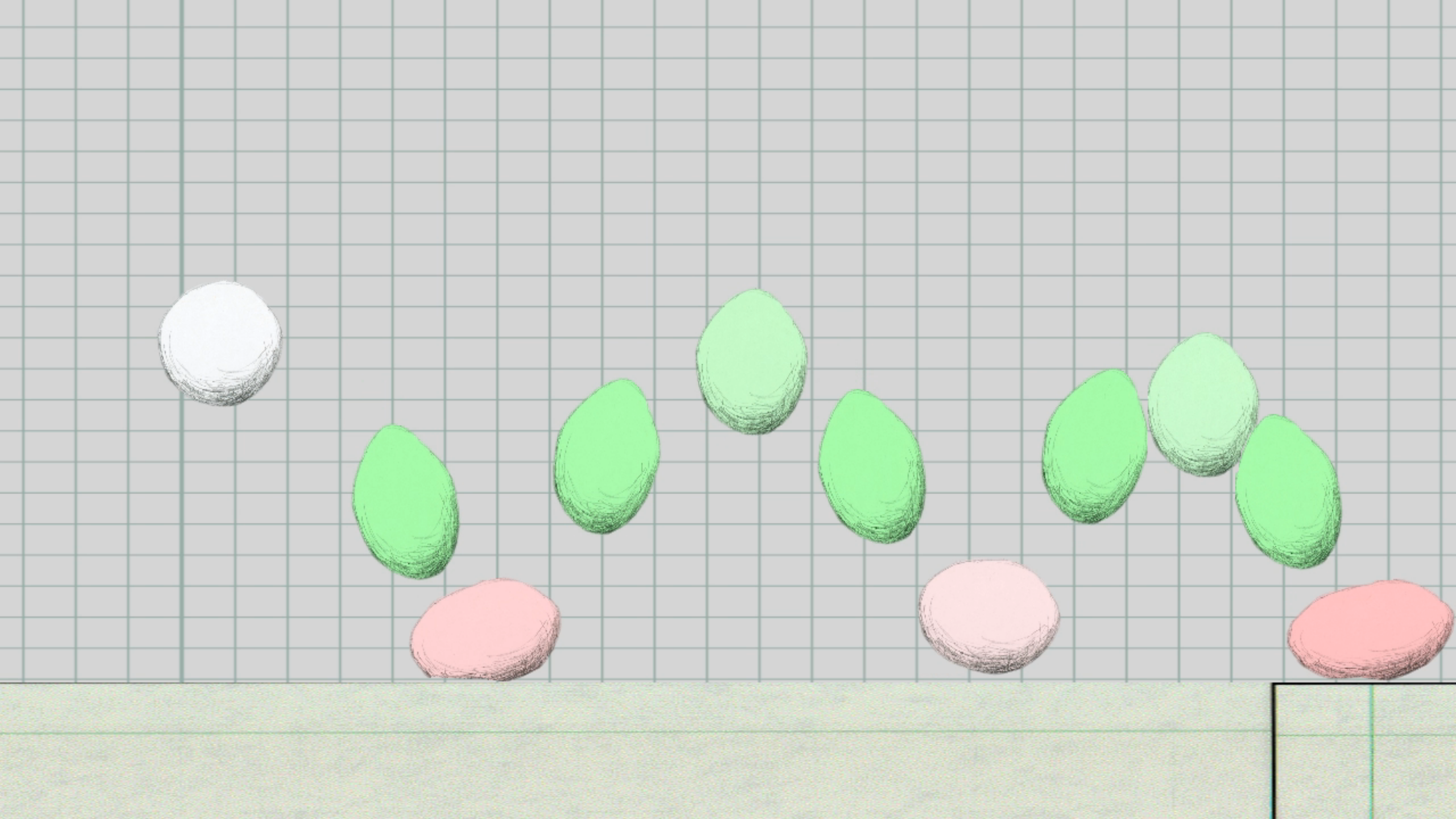


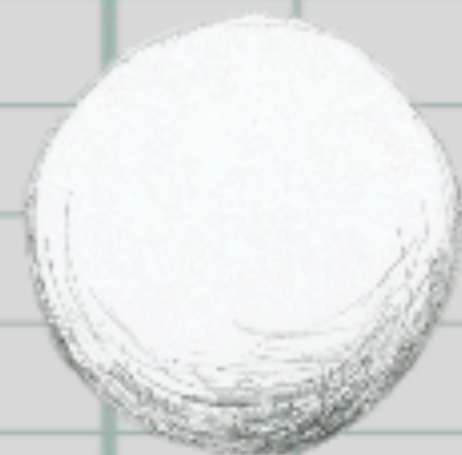
Other Controls

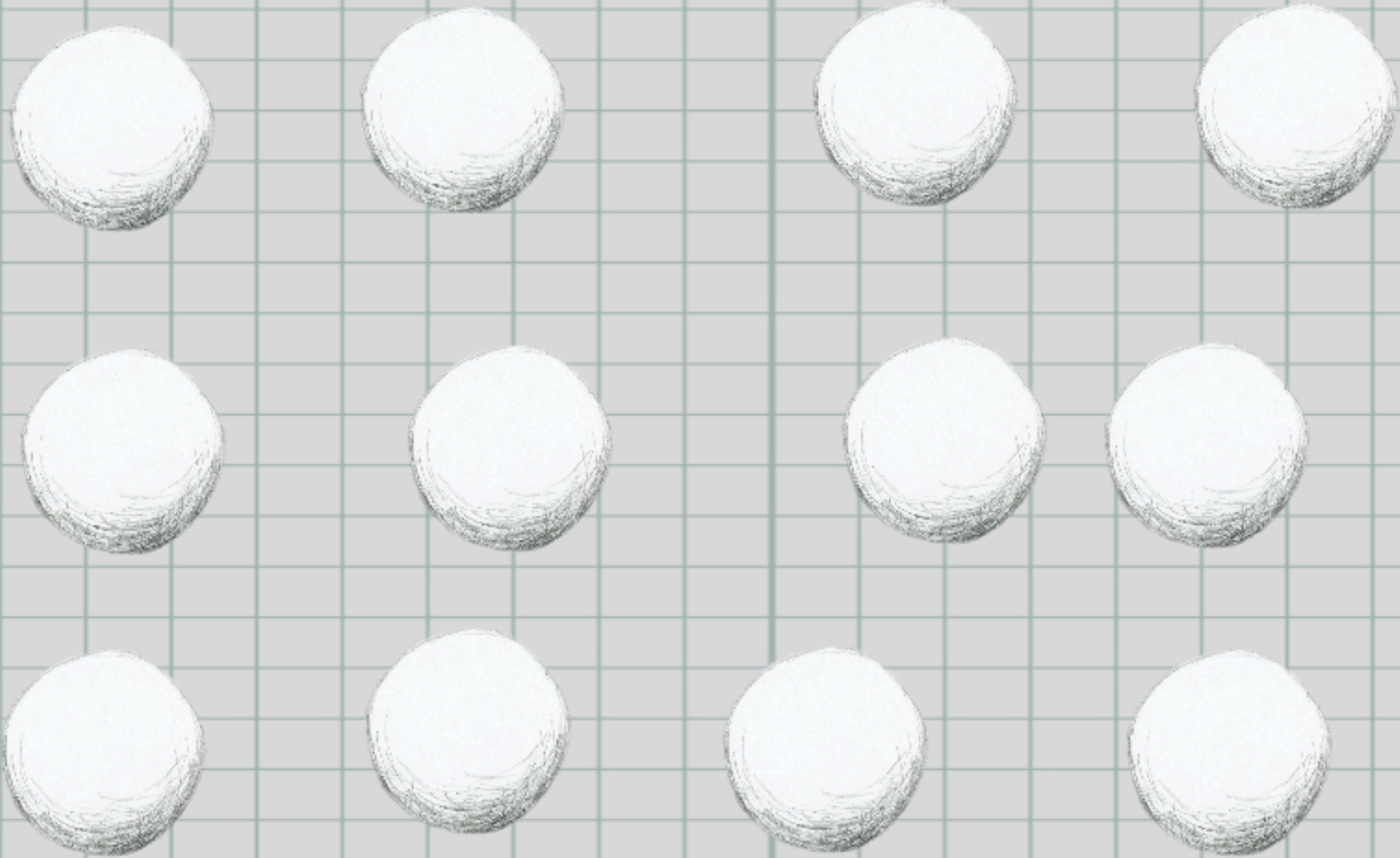
- ❖ Applying additional controls is simple in position based framework
- ❖ Controls can depend on arbitrary properties of the object
 - ❖ speed
 - ❖ orientation
 - ❖ angular momentum
 - ❖ ... etc





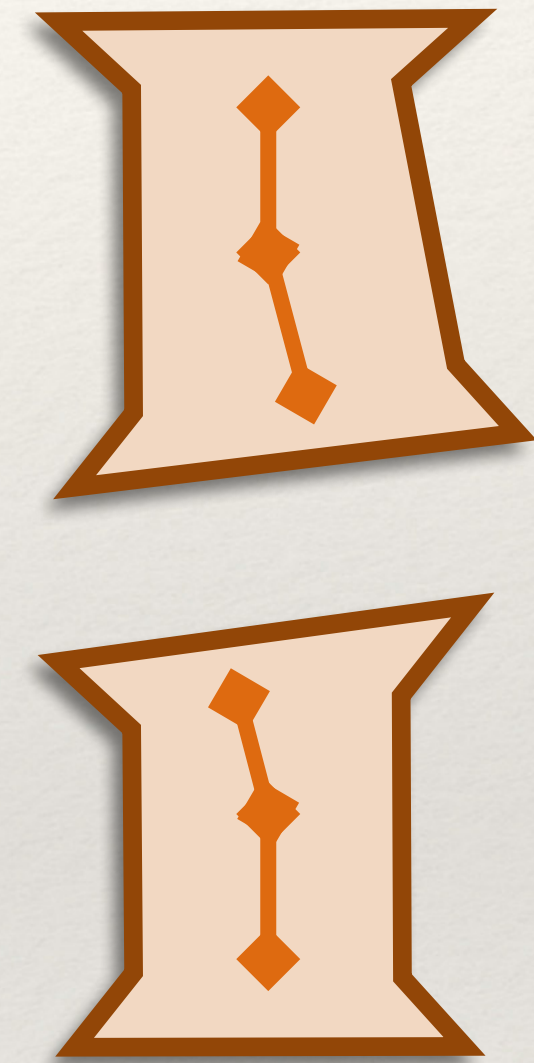
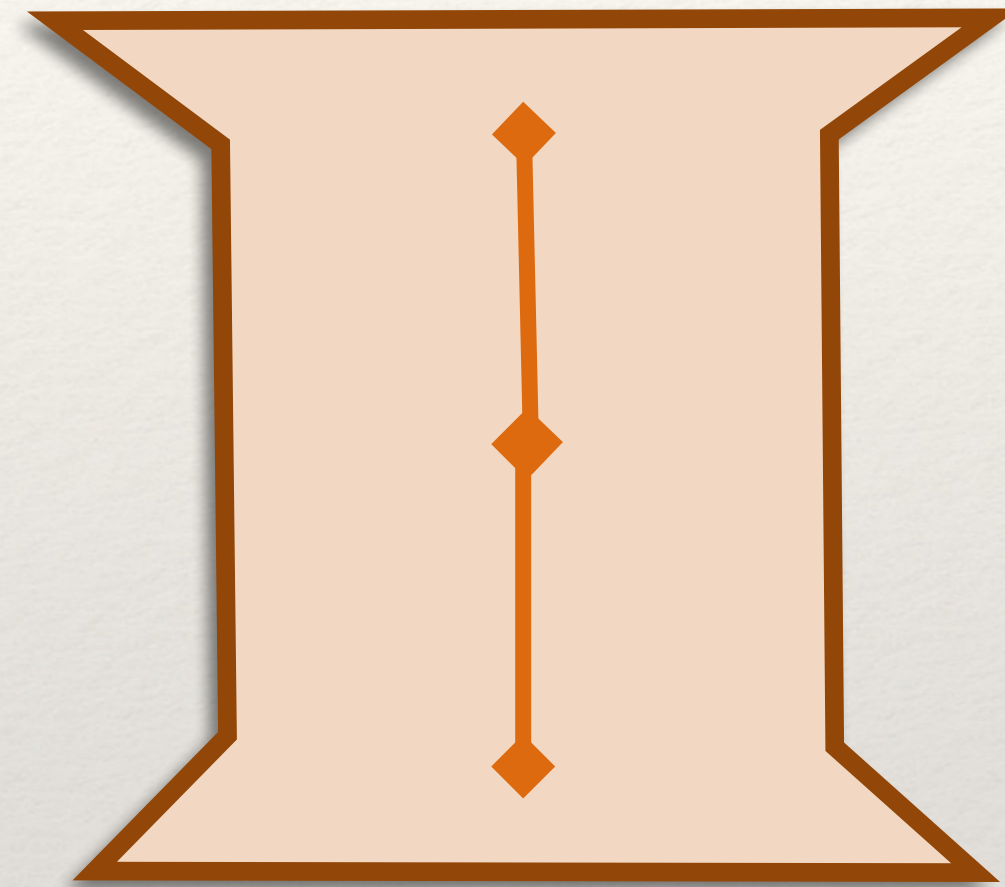
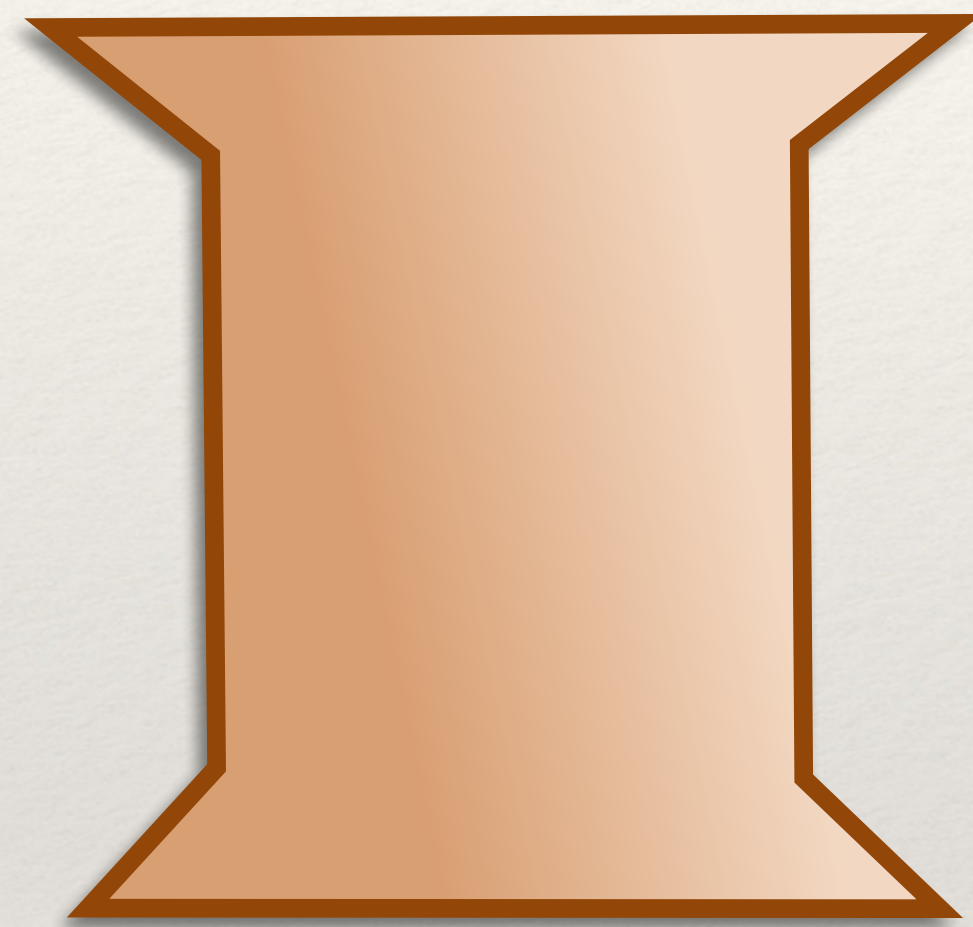






Applied to Destruction

Authoring

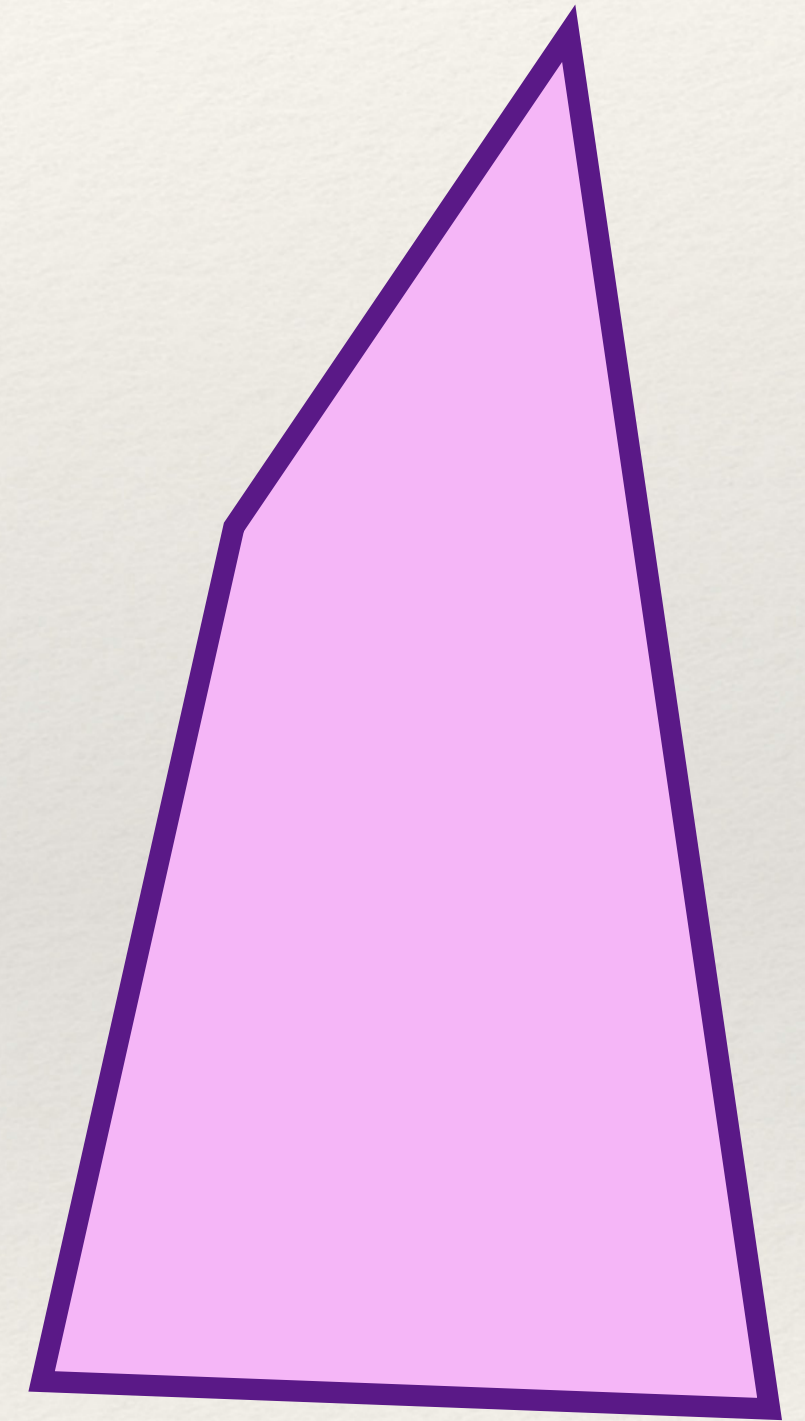
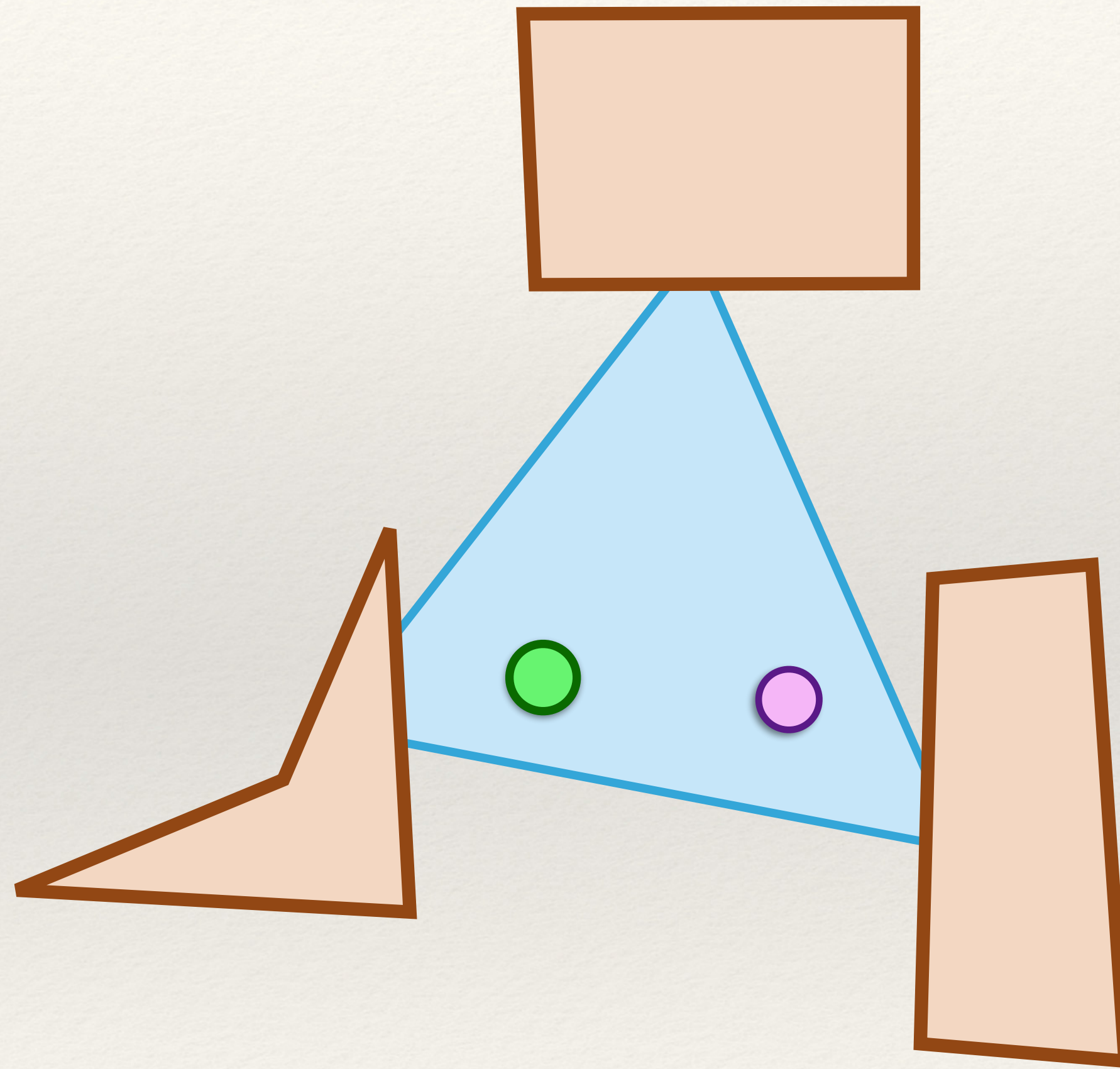
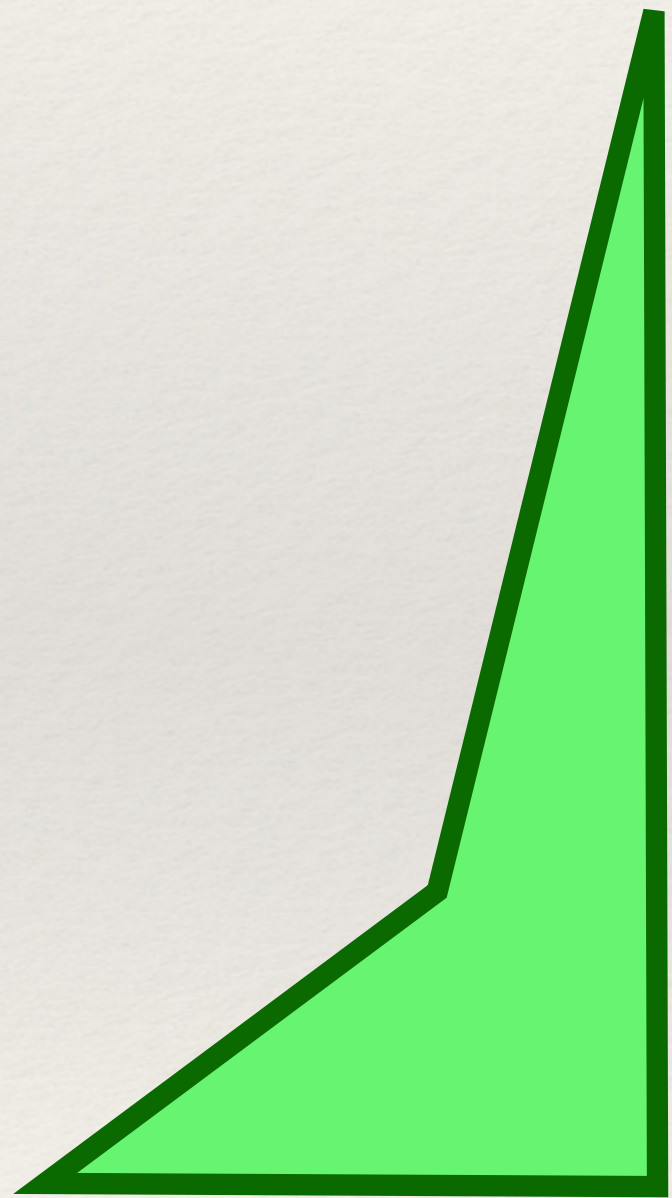


Input
geometry

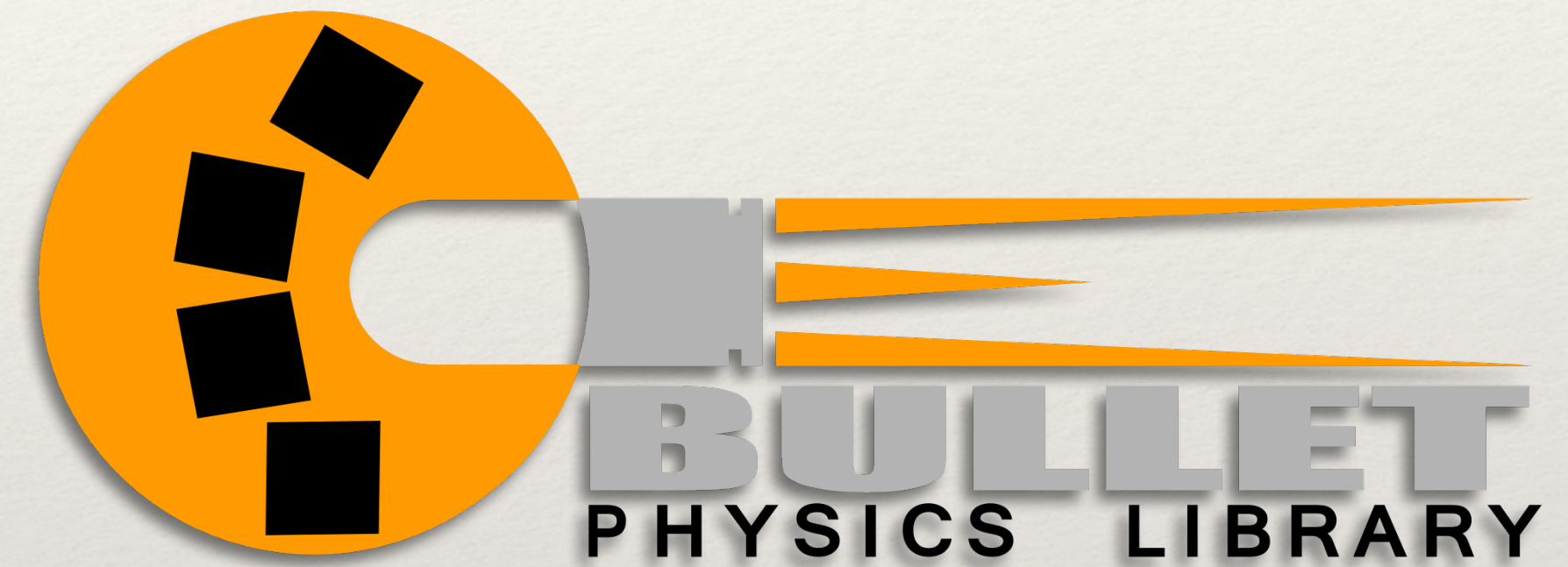
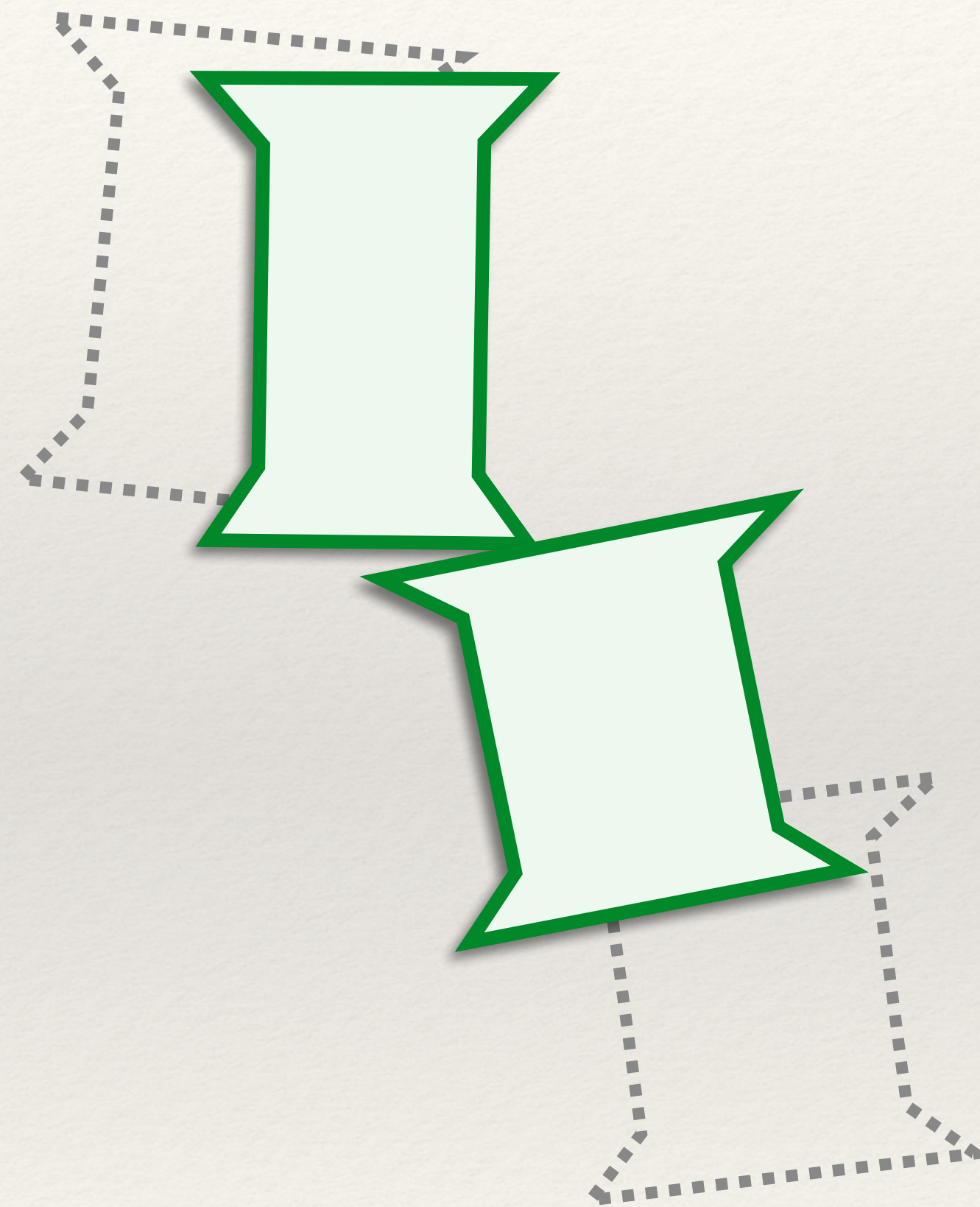
Rig

Characteristic
Deformations

Example Manifold

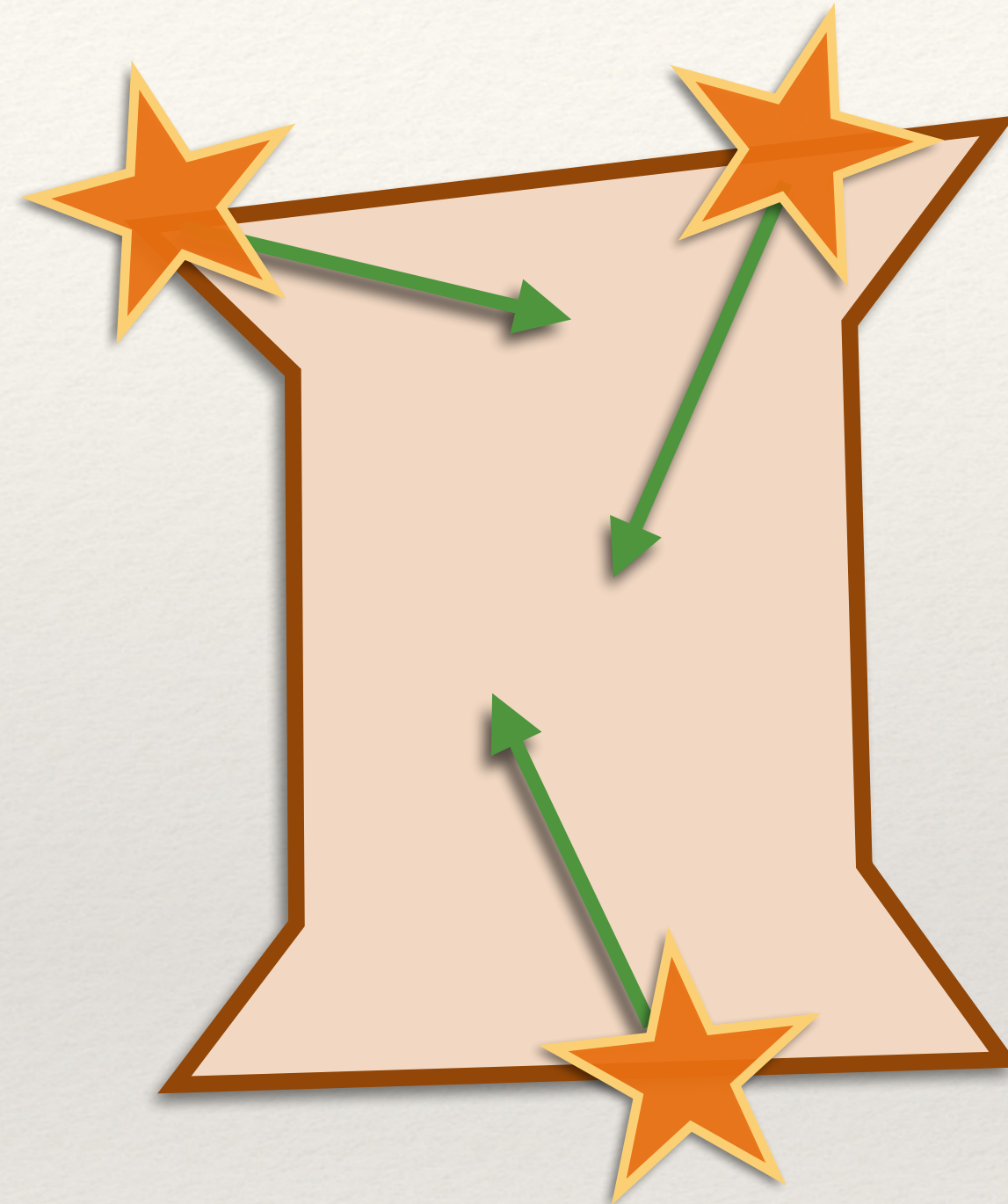


Simulation



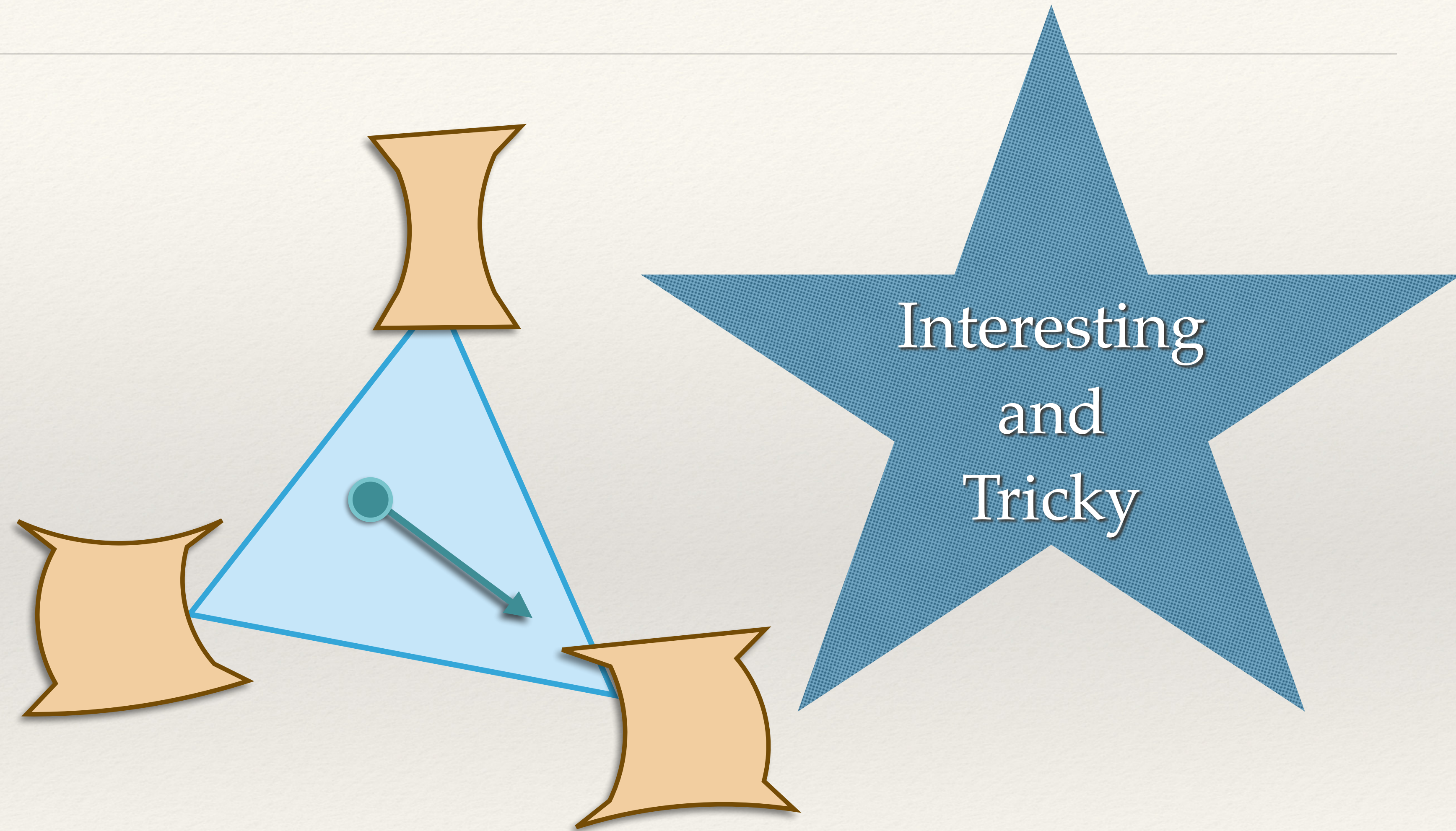
Unmodified Rigid Body Simulation

Simulation



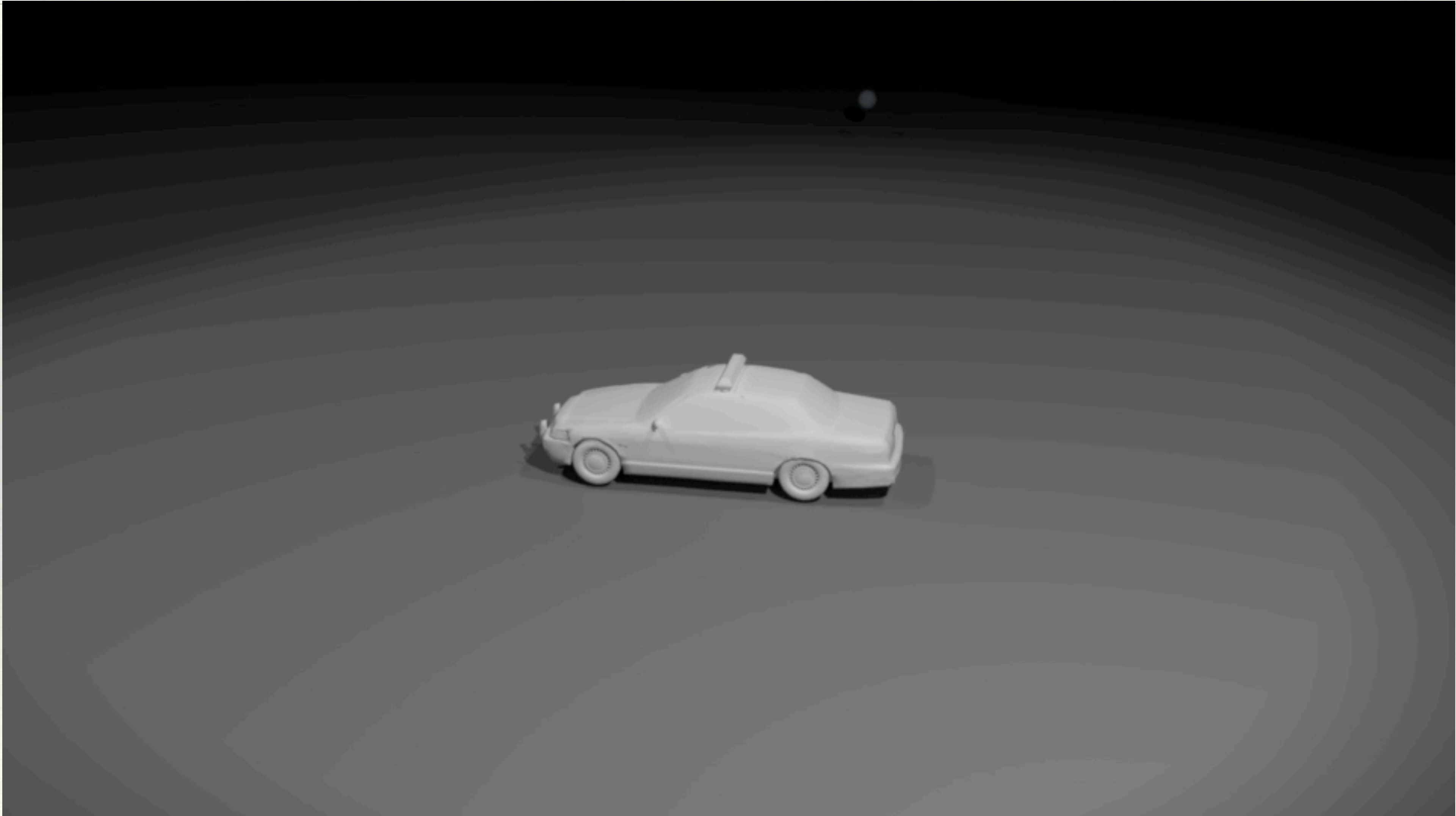
Collect Impulses

Simulation

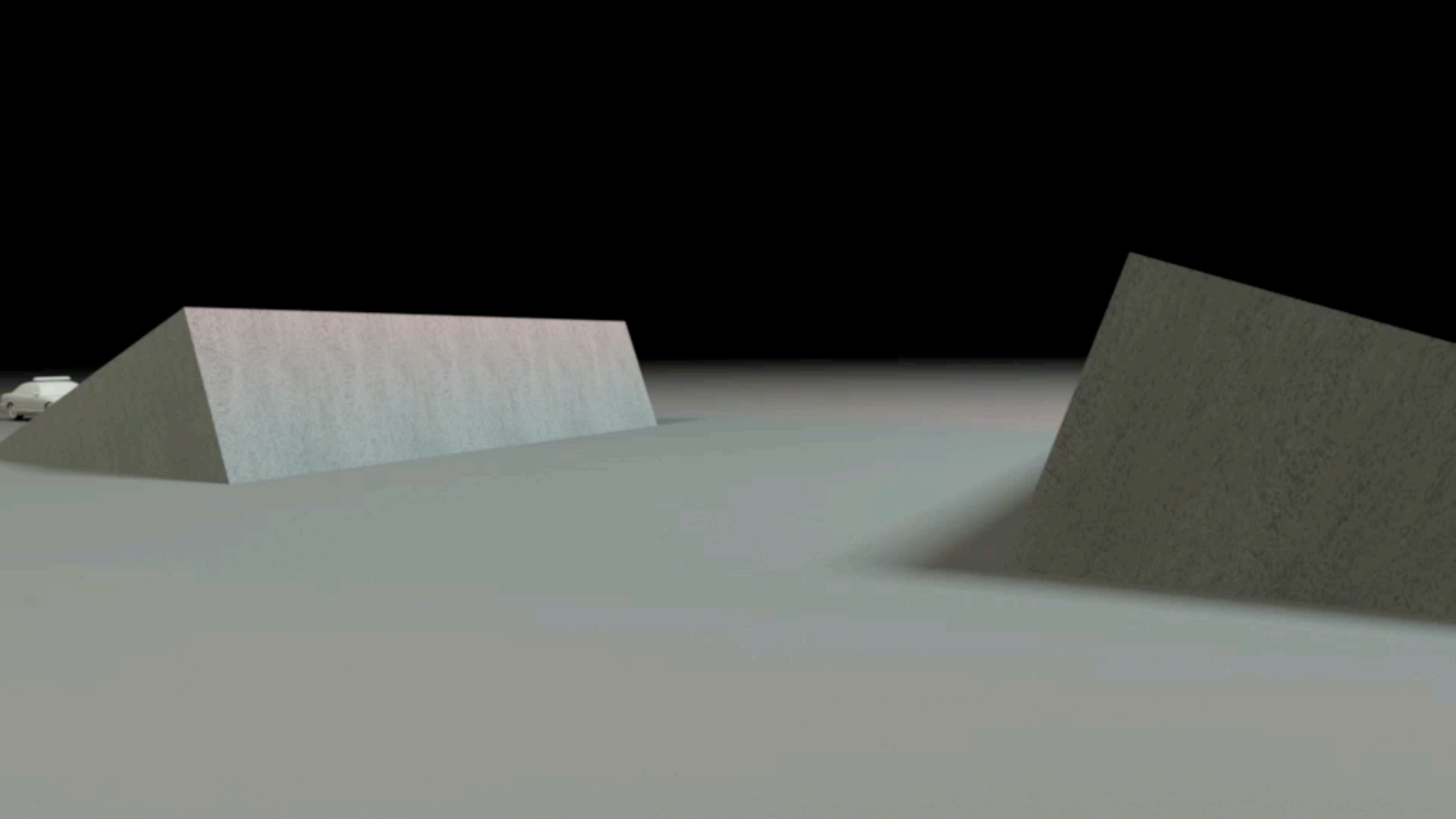


Update Example Interpolation Weights

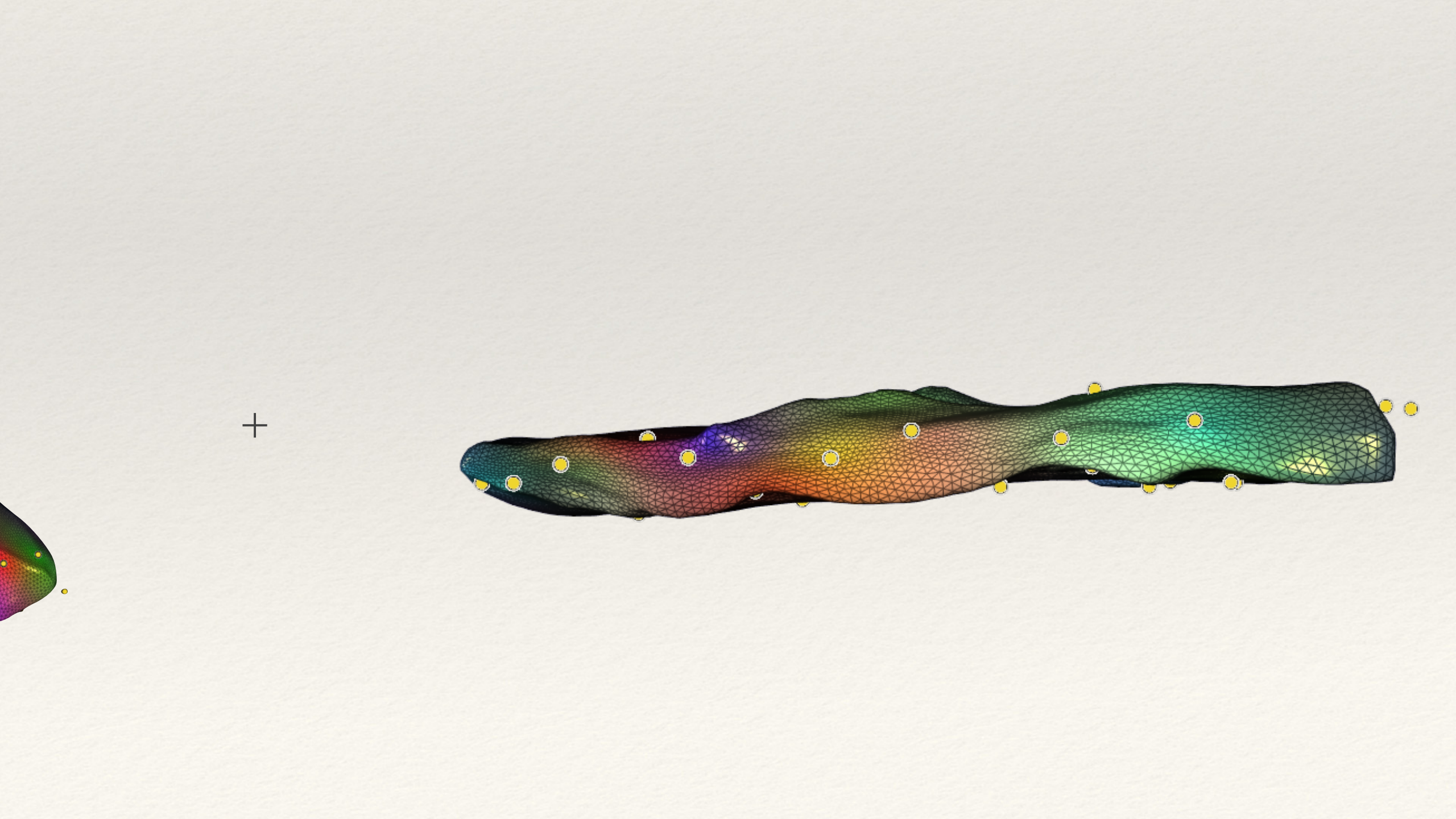
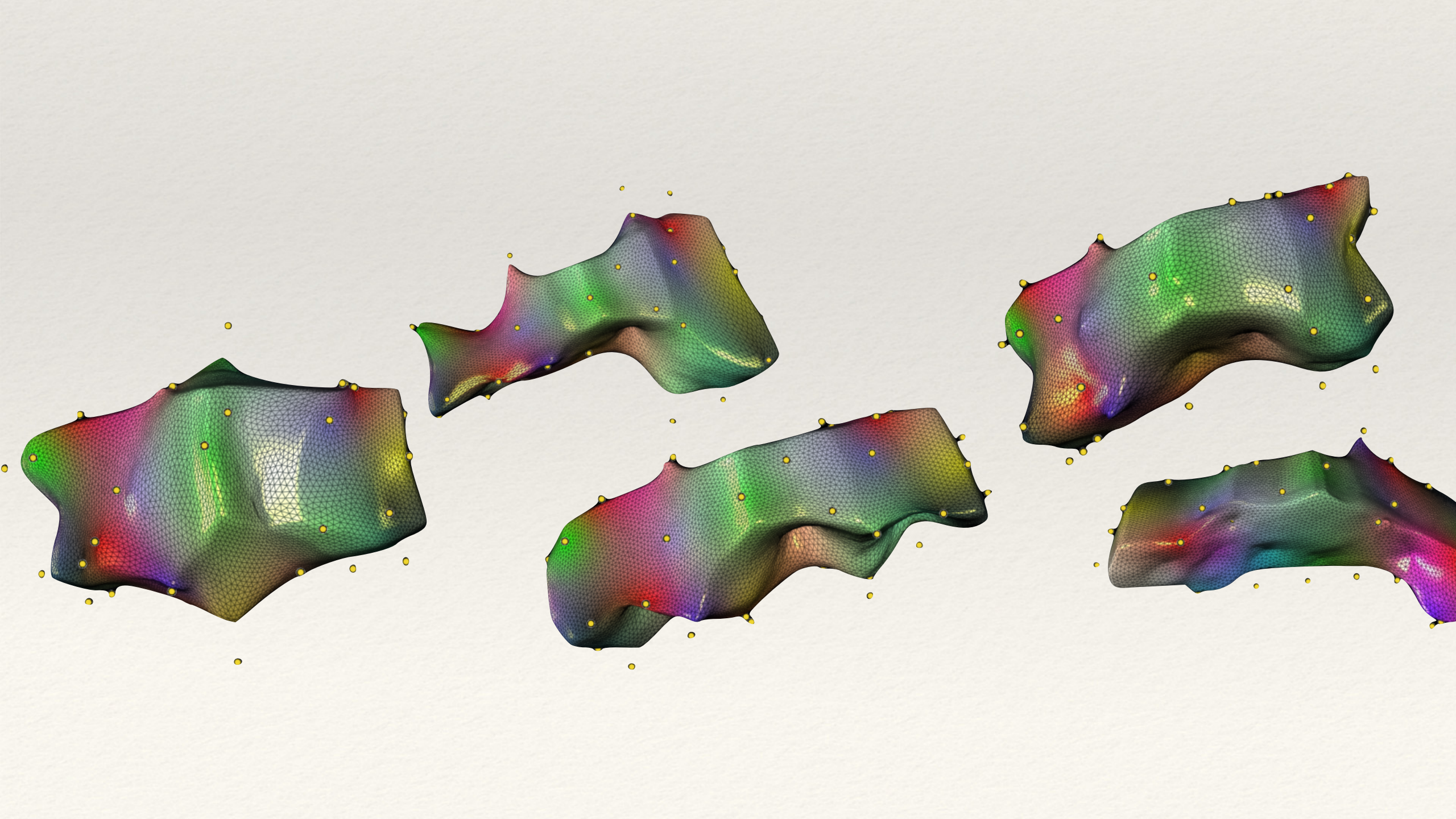
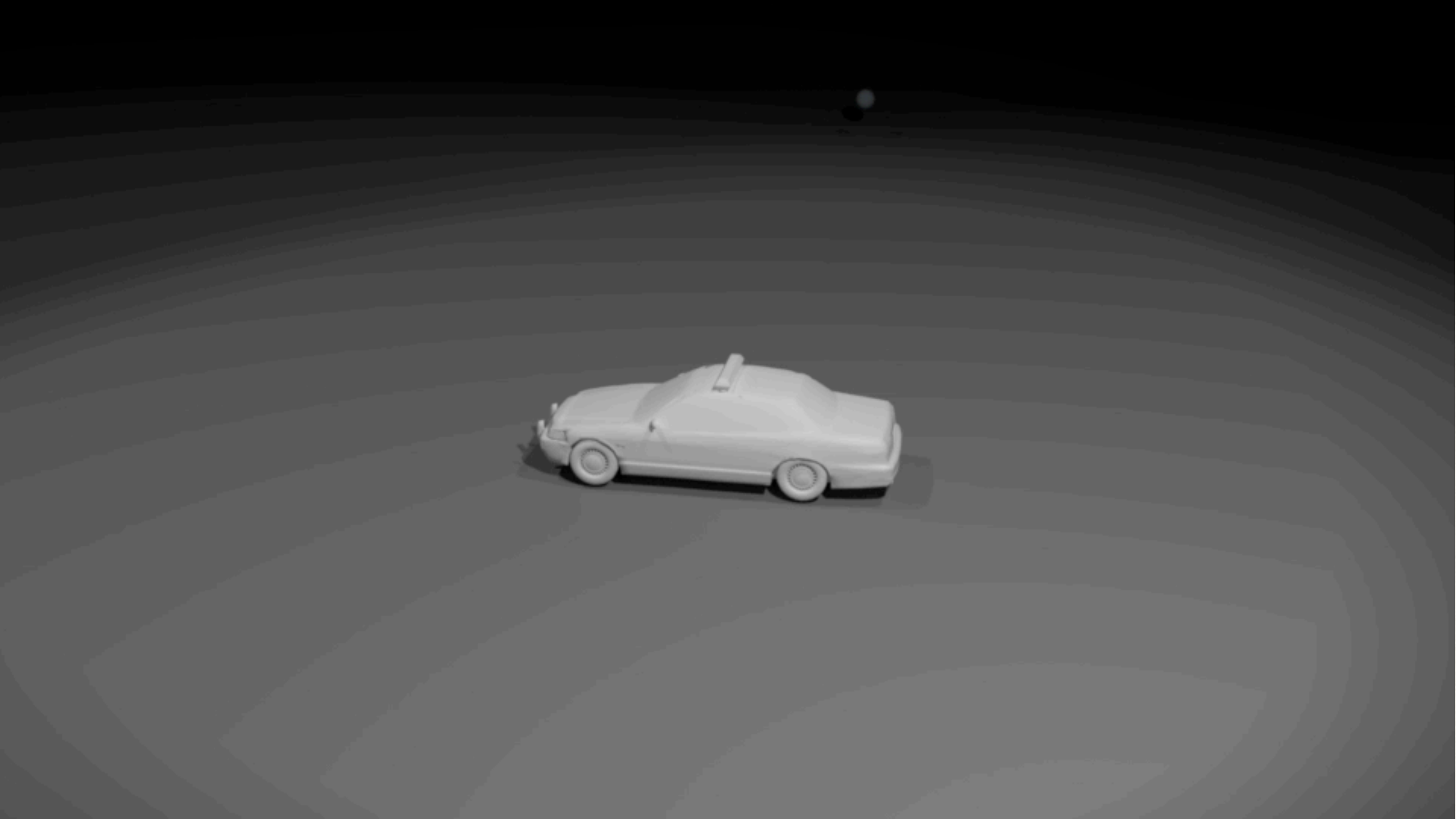
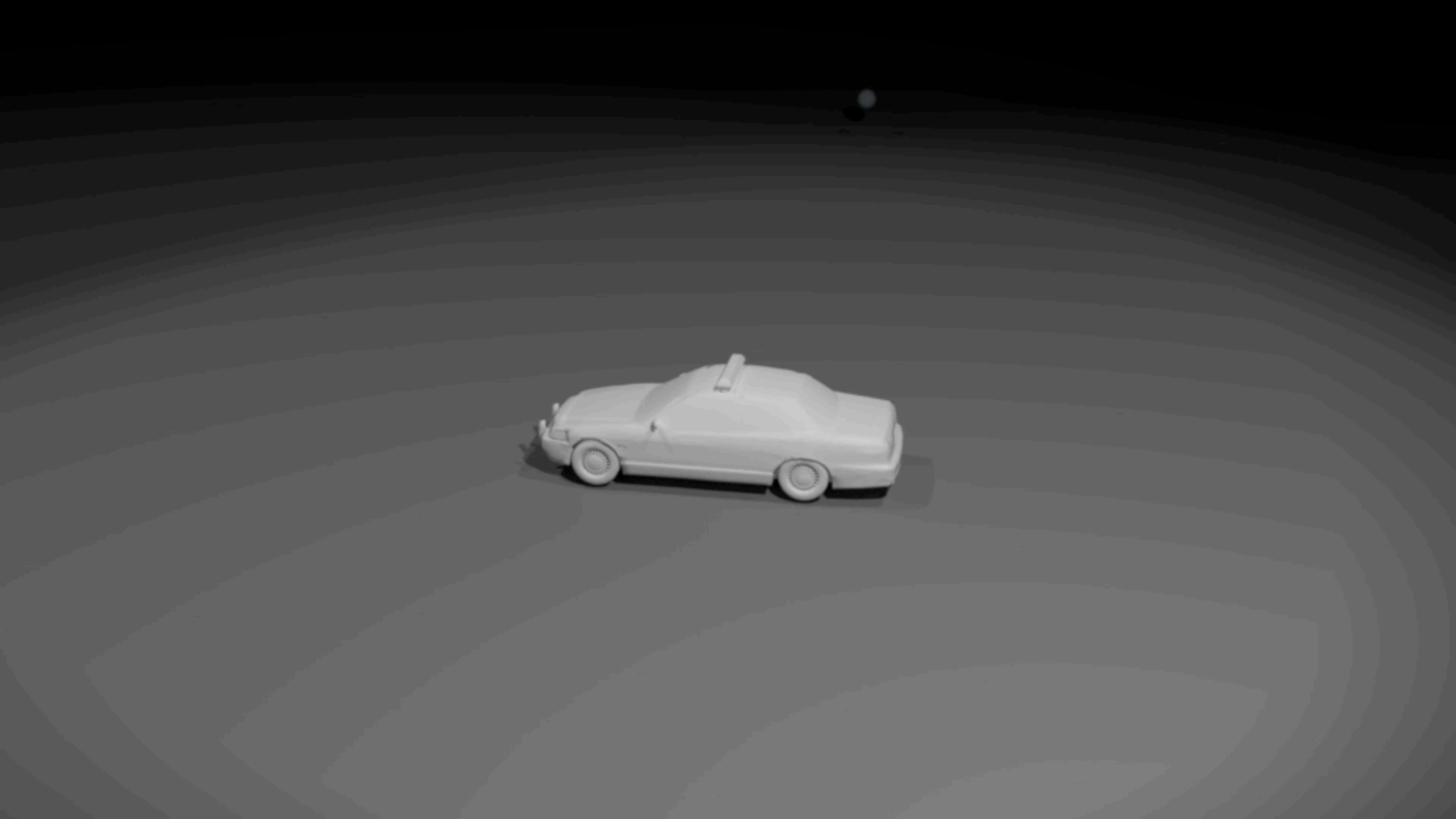
Sample Result



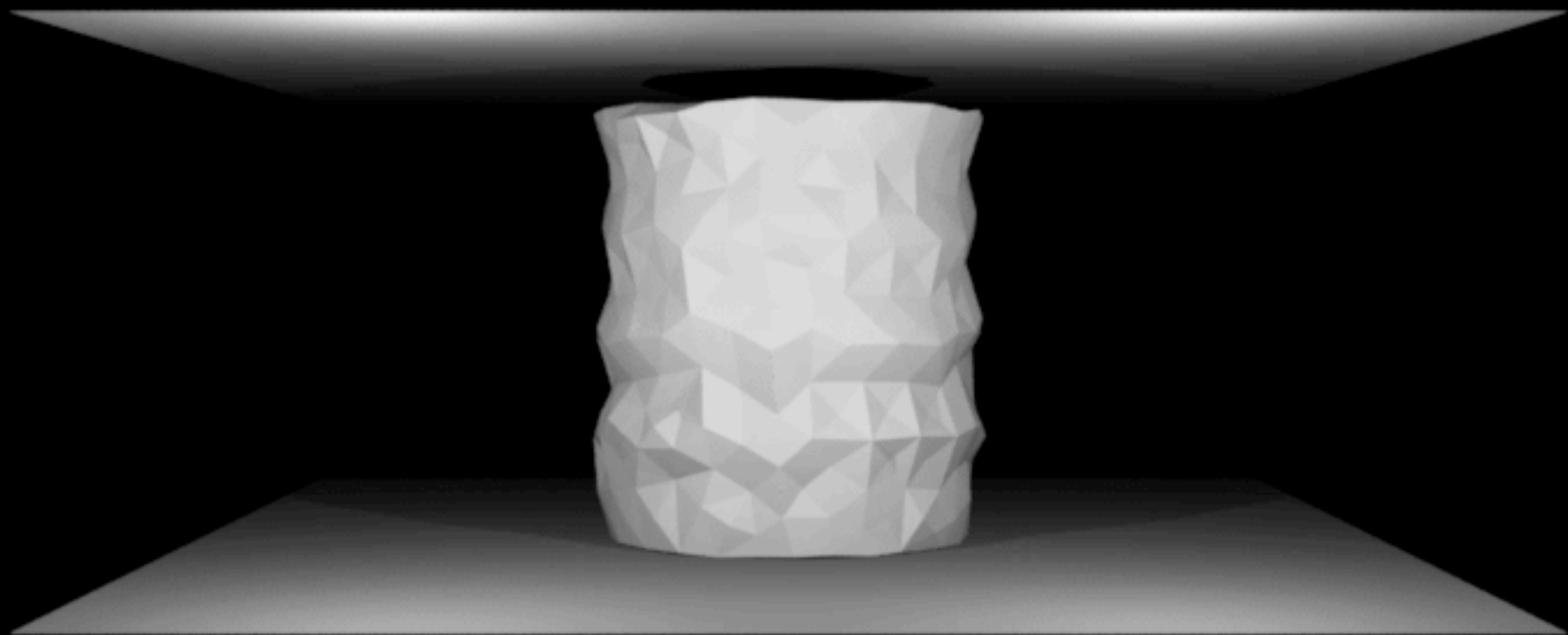
Car Launch

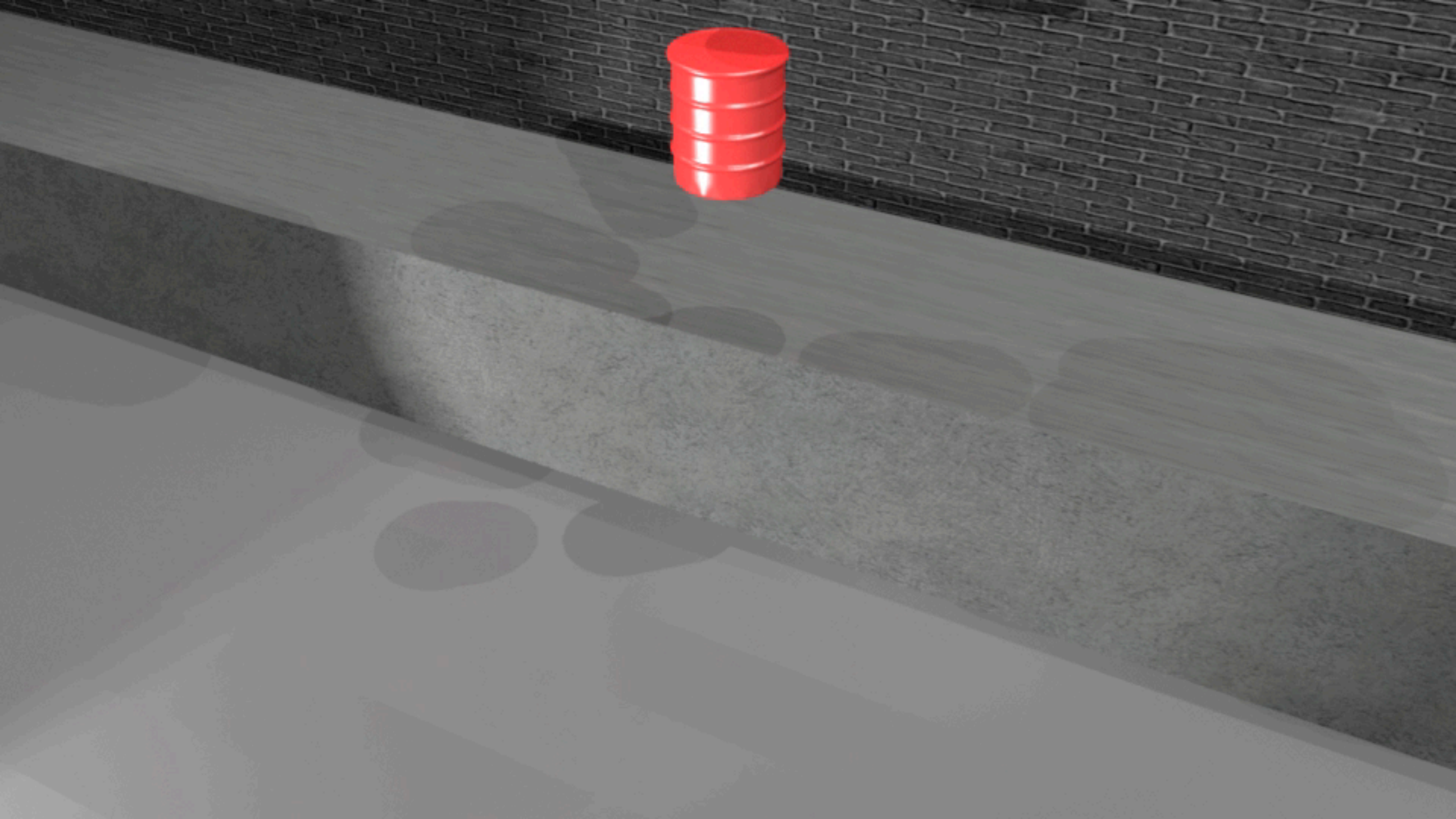


Example Iteration

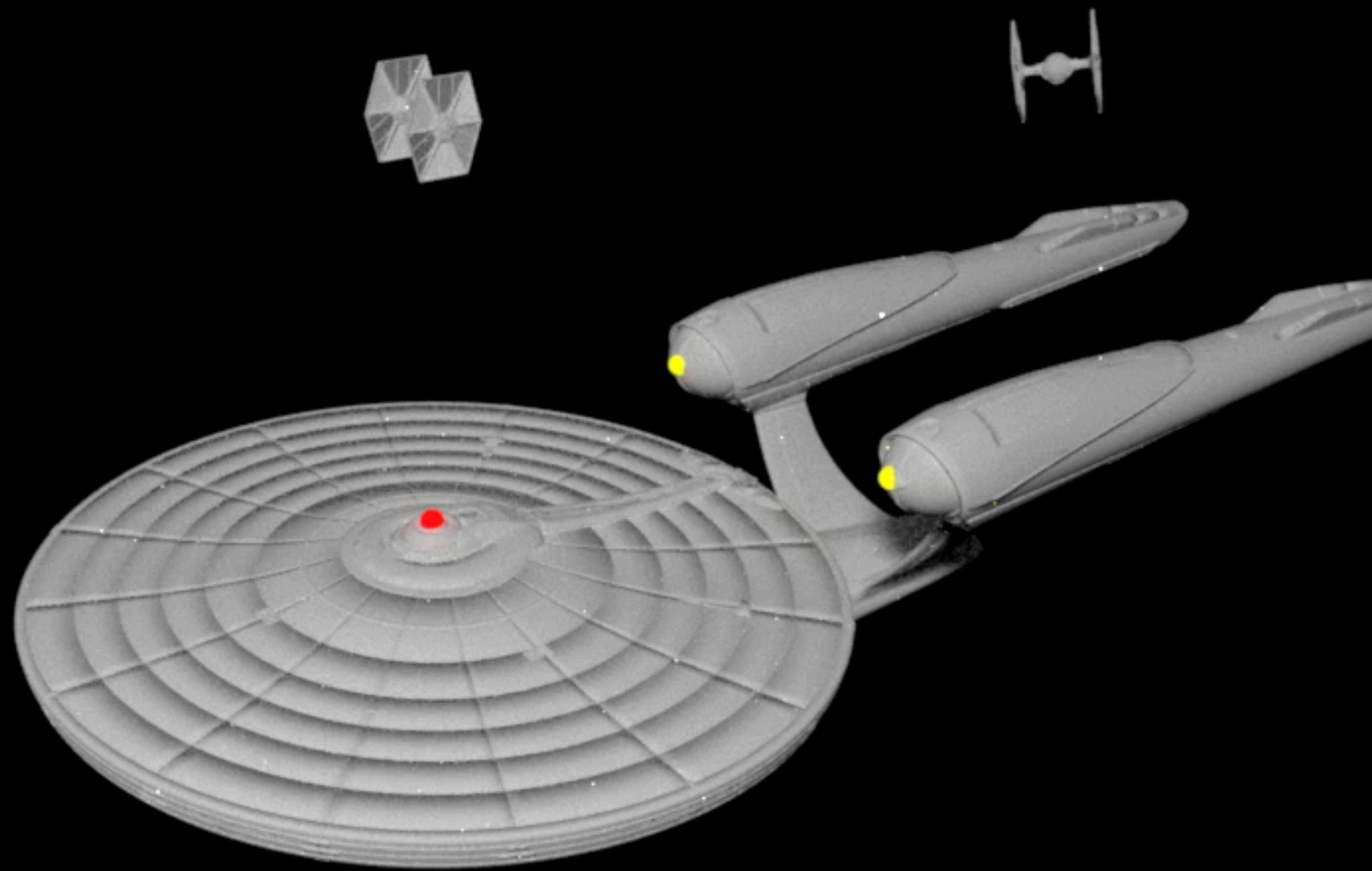


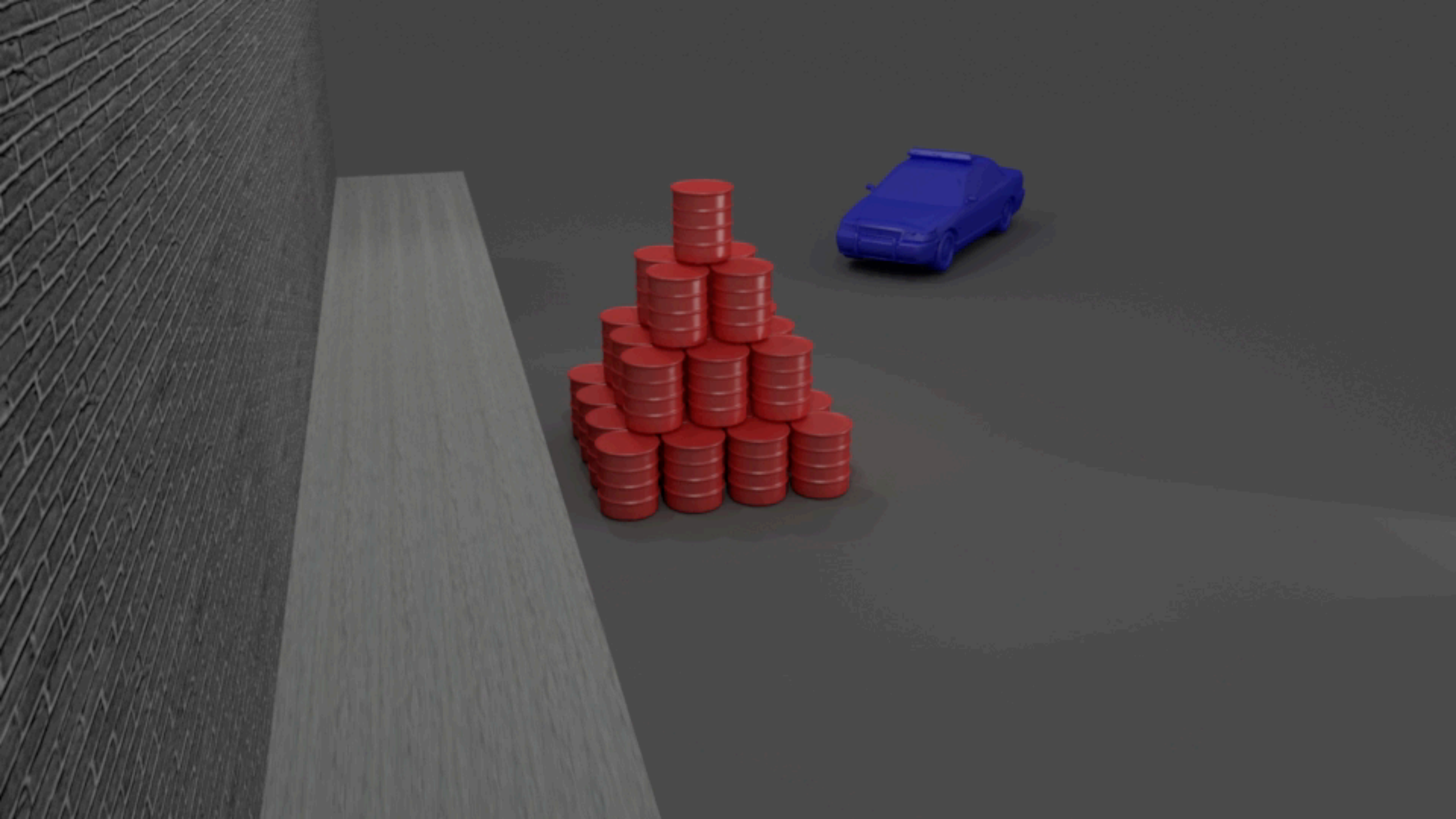
Physics imitating art imitating physics





JJ Abrams Fanfic





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