GDC SUMMER

How to Dissect an Exploding Spaceship In Hardspace: Shipbreaker

Richard Harrison
Technical Director

GAME DEVELOPERS CONFERENCE
AUGUST 4–6, 2020 | #GDC20

SETTING THE STAGE

GOALS

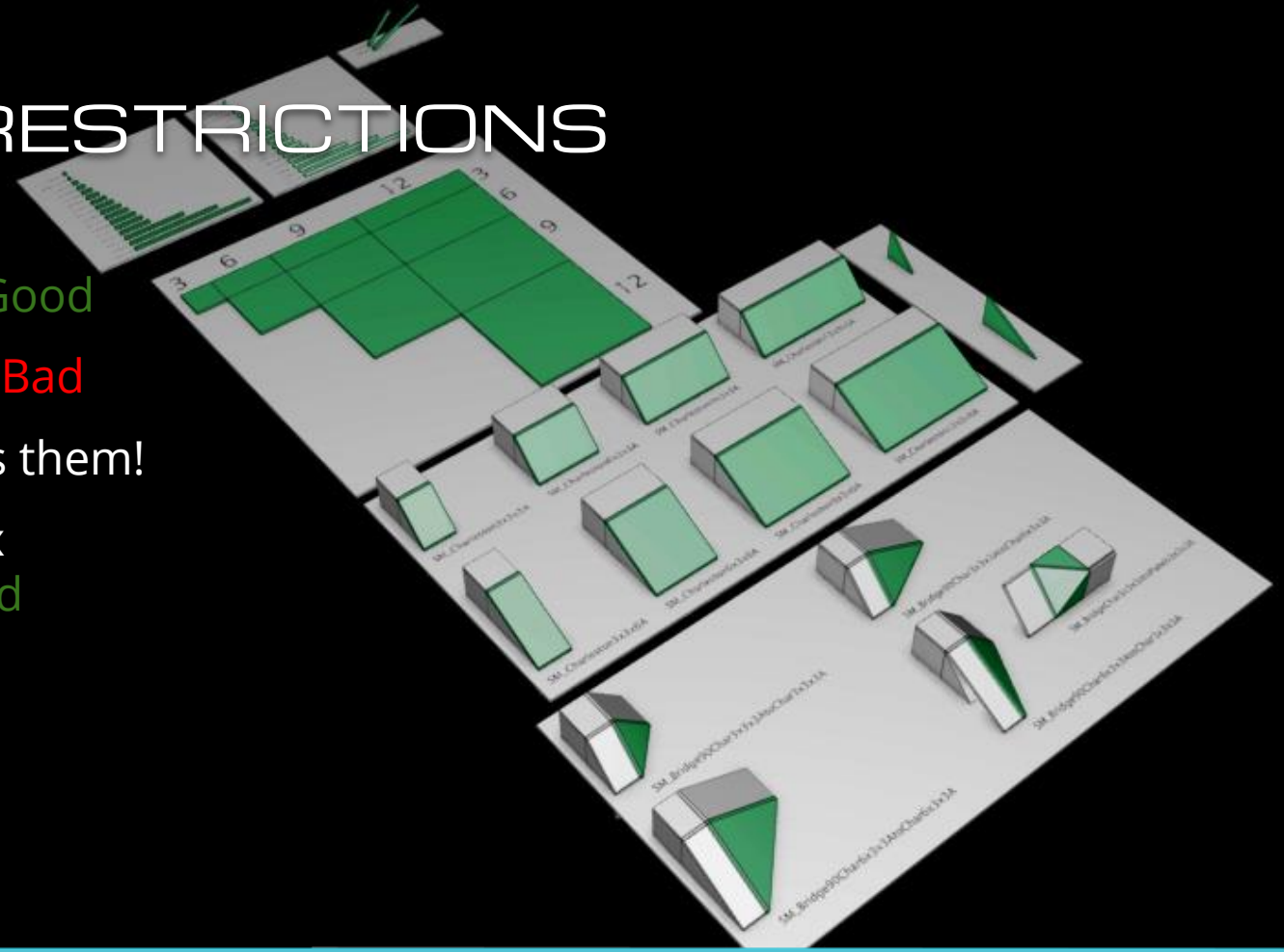
- Cut meshes from any angle
- Structural cohesiveness
- Interactive material types

GOALS

- Cut meshes from any angle
- Structural cohesiveness
- Interactive material types
- Player death

PHYSICS RESTRICTIONS

- Convex meshes Good
- Concave meshes Bad
  - Physics hates them!
- Groups of convex meshes also Good



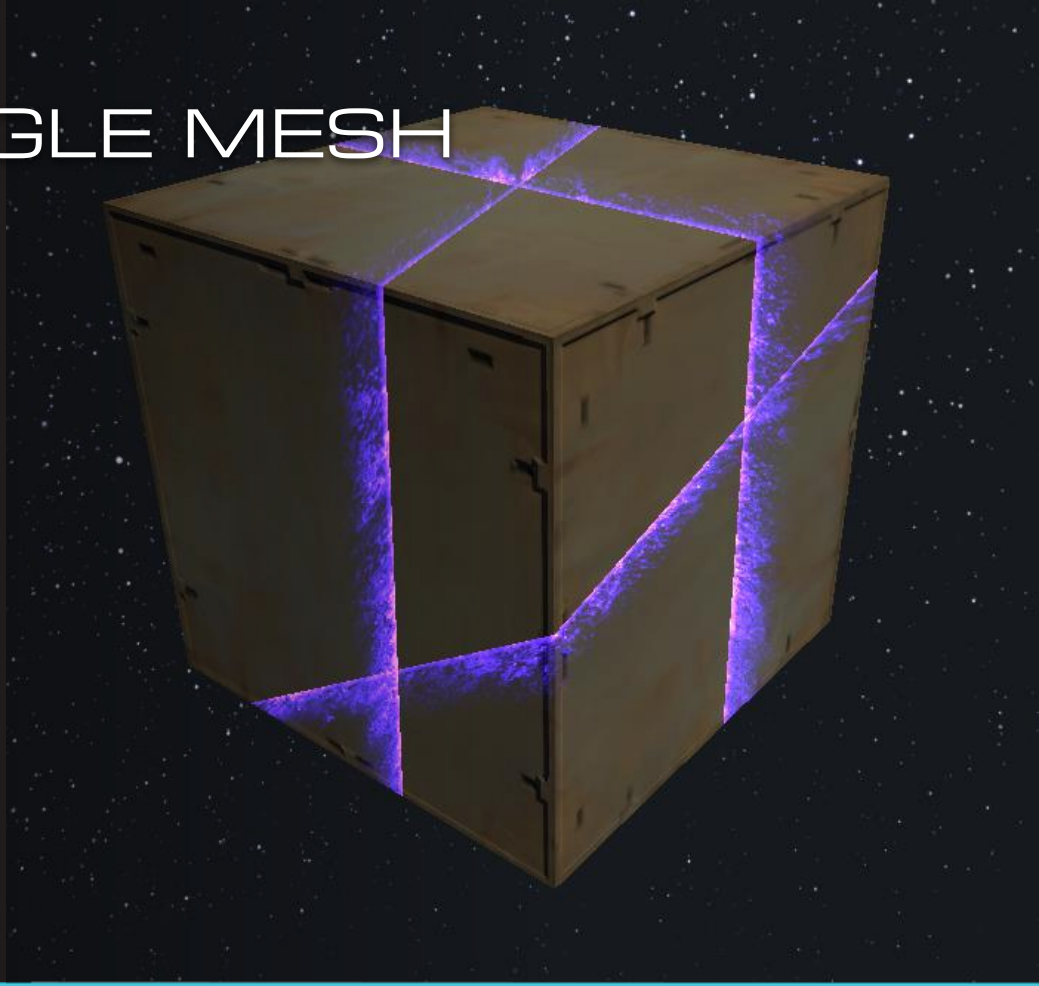
STARTING SMALL

GETTING STARTED

- Let's start with this:
  - 24 vertices (8 x 3)
  - 12 triangles
  - Infinite possibilities

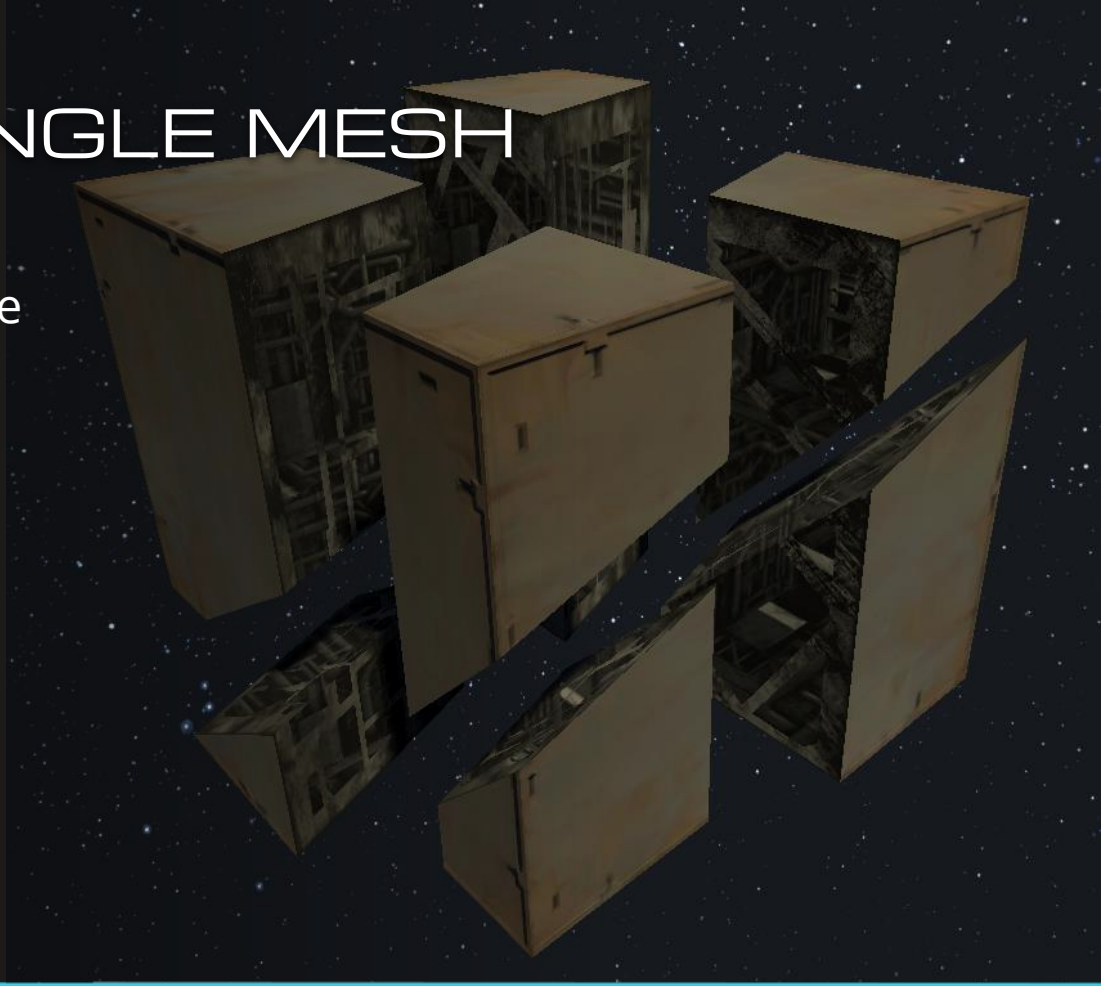
SPLITTING A SINGLE MESH

- Cut this cube from any angle
- Infinite cut-planes



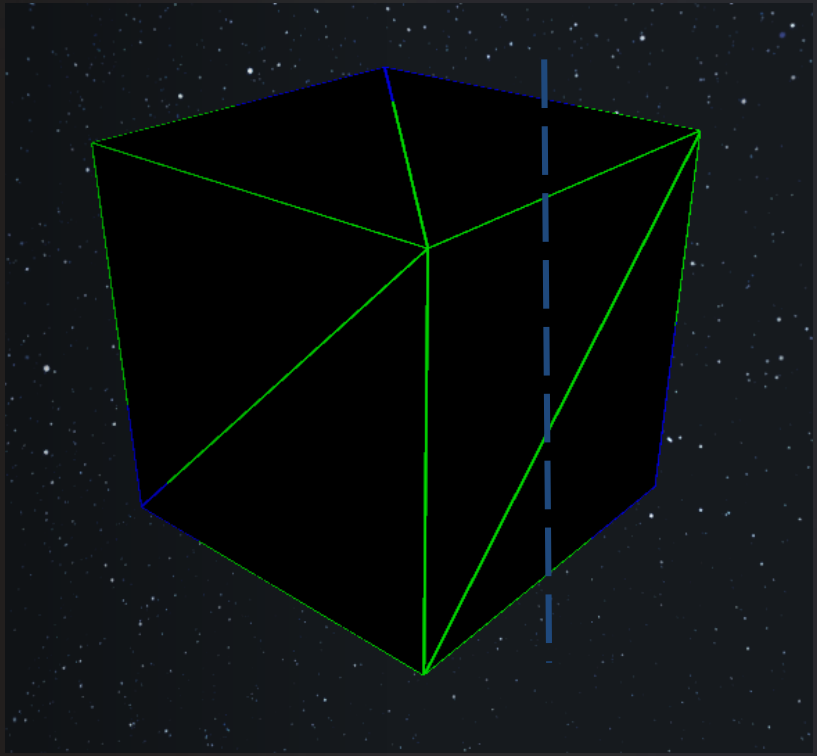
SPLITTING A SINGLE MESH

- Cut this cube from any angle
- Infinite cut-planes
- All that starts convex, stays convex



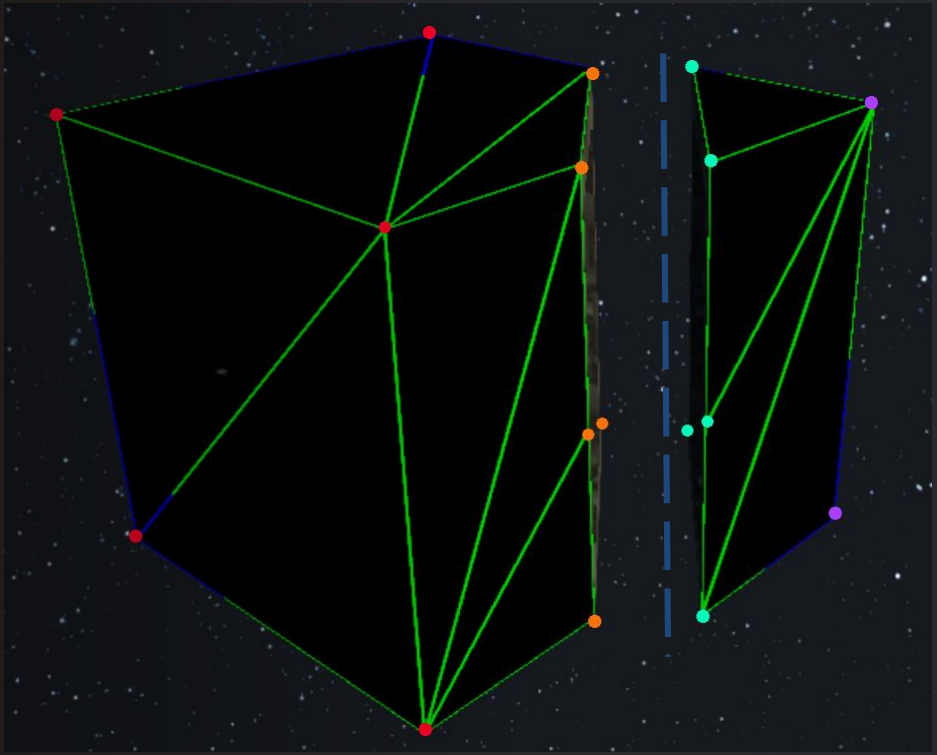
SPLITTING A SINGLE MESH

- Visualize the triangles…
  - Groups of 3 vertices



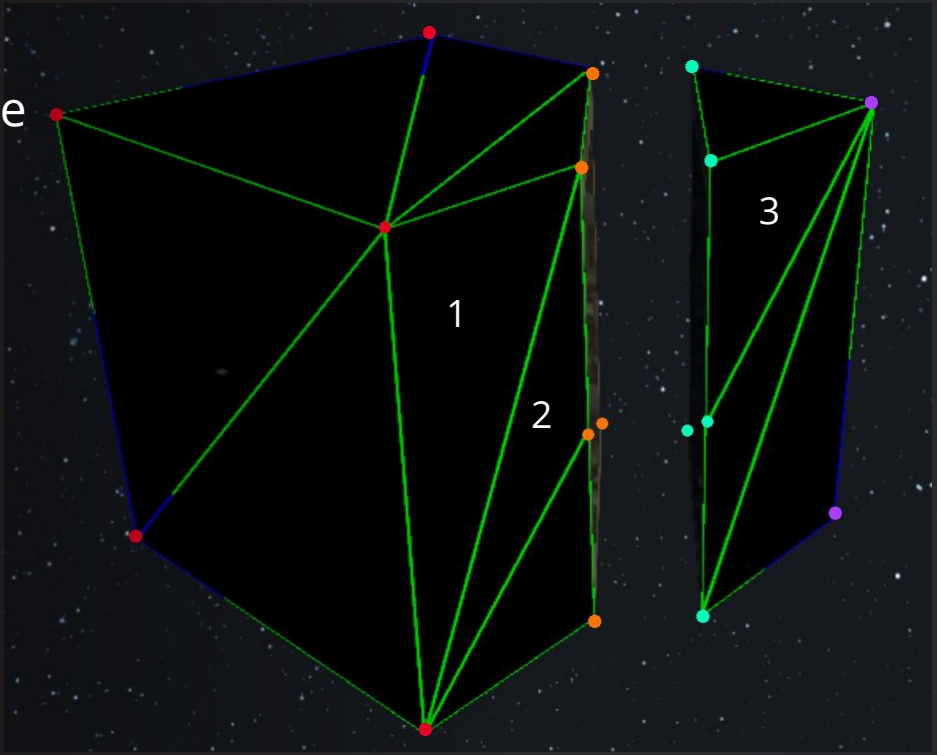
SPLITTING A SINGLE MESH

- On either side of the cut plane:
  - Sort | vertices
  - Sort unsplit triangles
- Split intersected | triangles



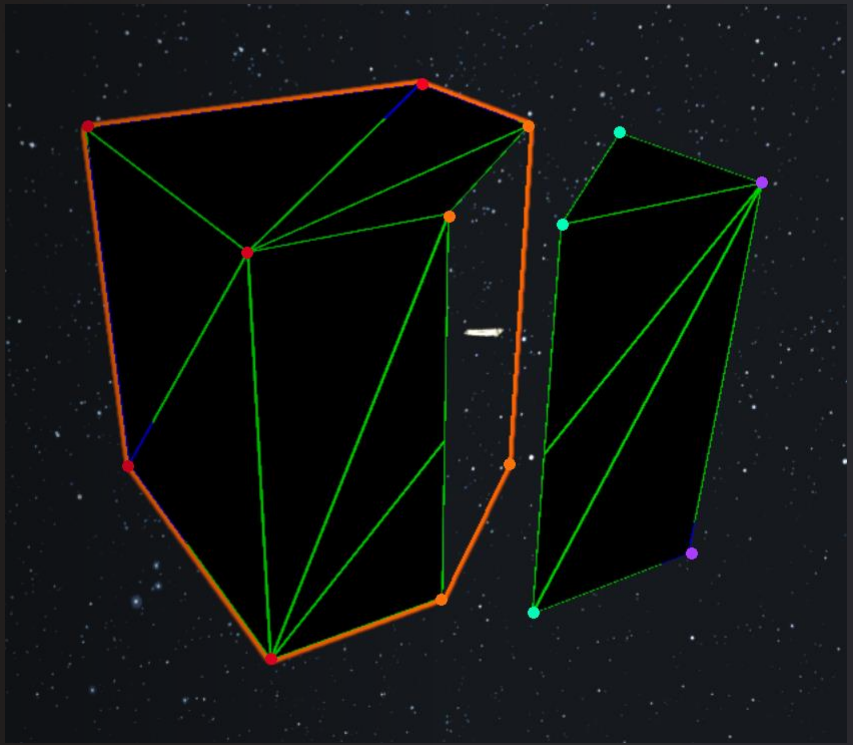
SPLITTING A SINGLE TRIANGLE

- One split triangle becomes three
- New intersected | vertices
  - Interpolate
    - UVs
    - Normals
    - Tangents
    - Colors



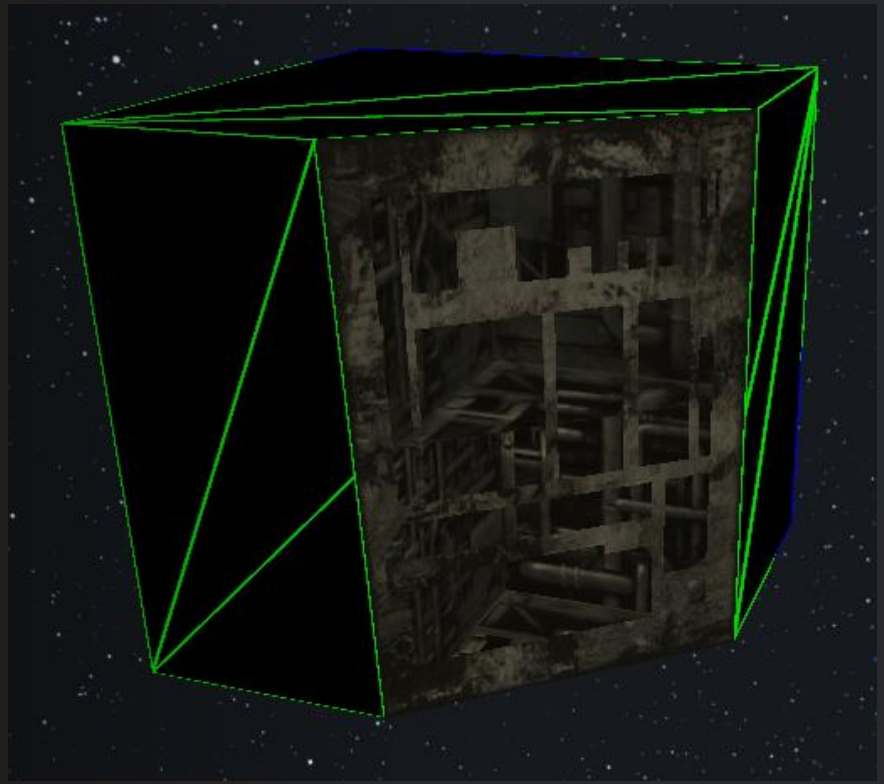
MESH INTERIOR MAPPING

- Meshes are like papier-mâché
  - Gotta fill it!
  - Reuse intersected | vertices for new triangles
  - Centroid fan-fill triangulation
  - Project vertices to cut plane for UVs



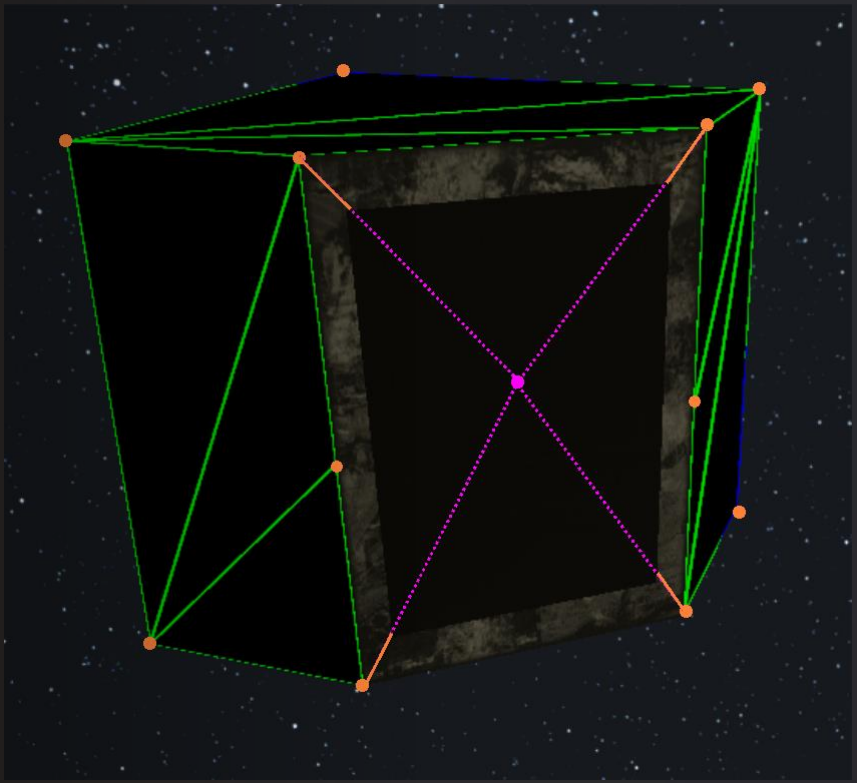
WATERMELONING

- Better representation of an “edge”
  - Display thickness for realistic interiors
  - Parallax maps for depth



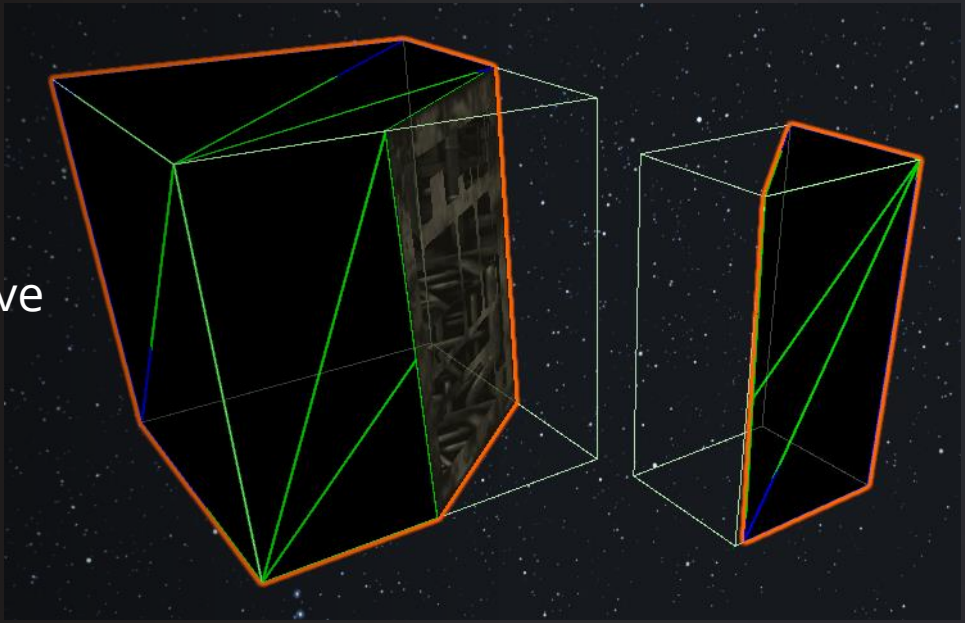
WATERMELONING

- Triangle-based distance field
  - Exterior and Interior vertex colors
  - Centroid is an Interior vertex
  - Shader maps textures to edges
- Exterior | Exterior = Exterior
- Interior | Anything = Interior



SPLITTING A SINGLE MESH

- But wait… the physics!
- Convex is Good!
- What are the resulting masses?
  - Accurate volume is expensive
  - Bounding volume is cheap
  - Relative to original mass



SWEET CROSS SECTIONS

- Split a mesh
- Do some Watermeloning
- Redistribute the Mass

- Make one believable object inside and out!
- But what about the rest…?

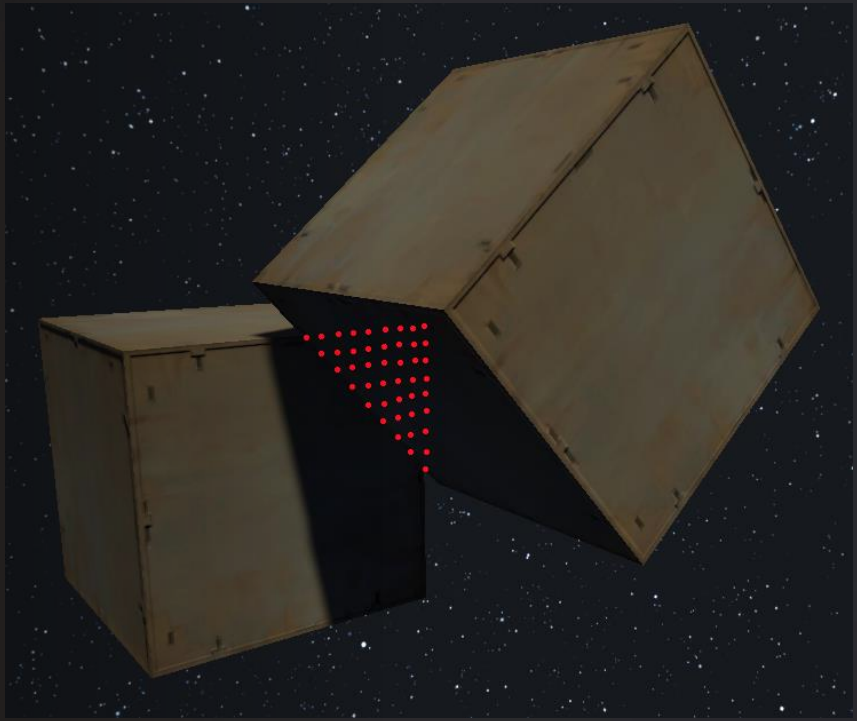
SPACESHIP GLUE

PIECING TOGETHER A SPACESHIP

- Ship pieces follow two rules:
  - Come apart when cut free
  - Stay together when still attached

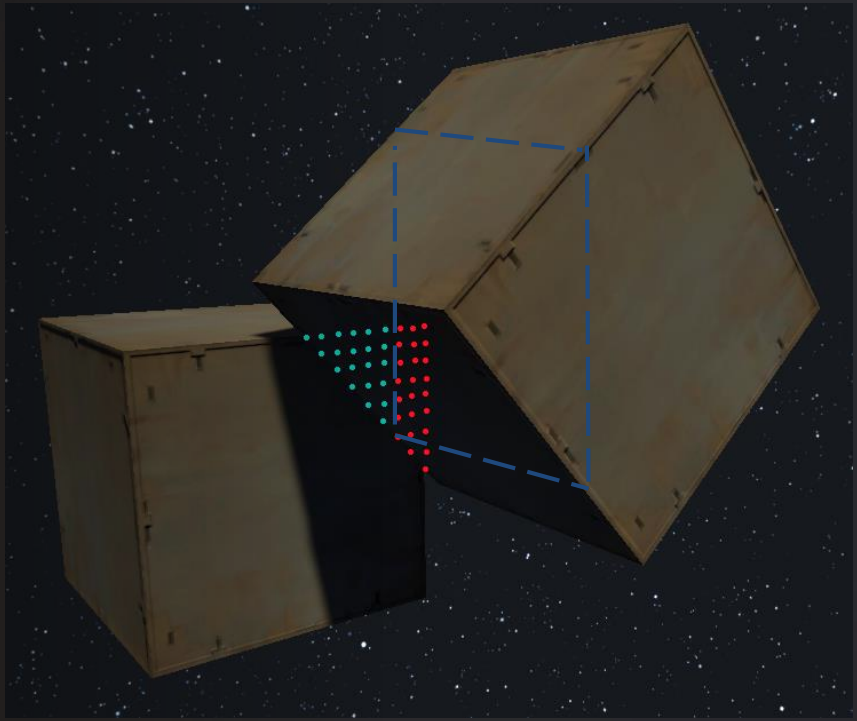
FIRST ATTEMPT: JOINT POINTS

- Points mean joints!
  - Points placed between flush-faces
  - Points between objects mean they are jointed



FIRST ATTEMPT: JOINT POINTS

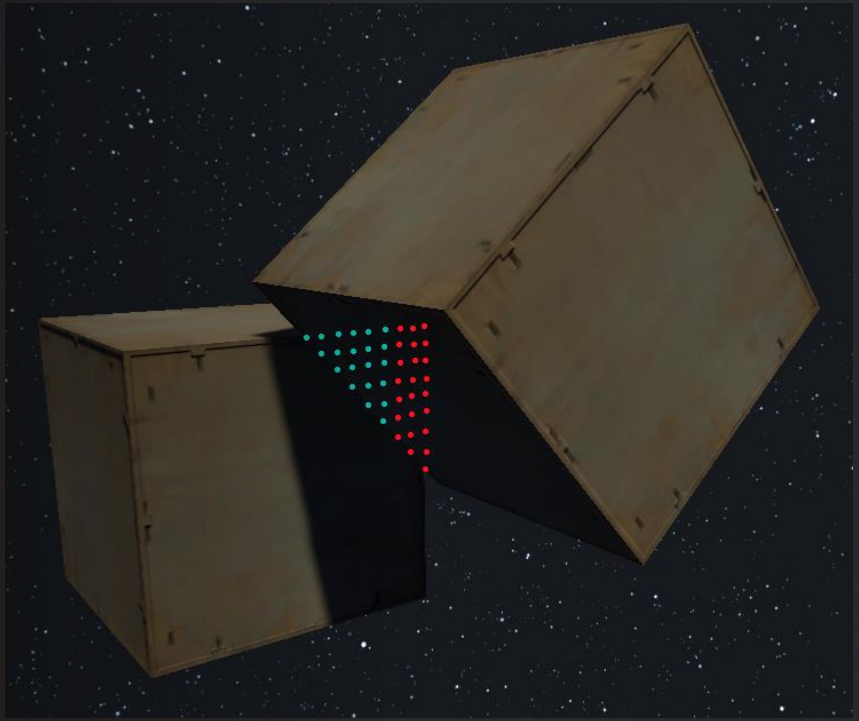
- Cuttable
  - Sort points like vertices
  - Reassign cut pieces



FIRST ATTEMPT: JOINT POINTS

- Good for connecting!
- Good for cutting!
- But…

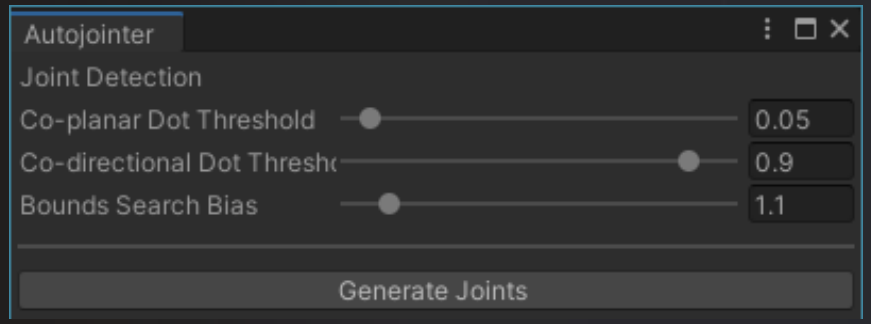
Time	Bad
Accuracy	Bad
User Error	Bad
Iteration Overhead	Bad
Bulky Data	Bad



AUTOMATIC JOINTER

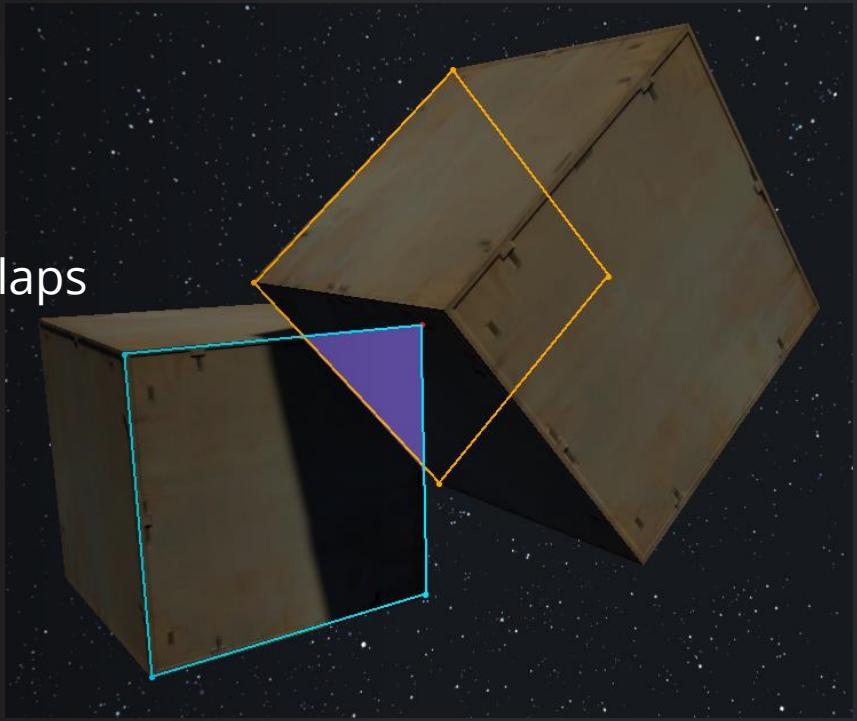
- Offline tool
- Find flush-faces, slap dots between
- 1+ hour to bake

Time	Better
Accuracy	Better
User Error	Better
Iteration Overhead	Better
Bulky Data	Bad



THERE MUST BE A BETTER WAY!

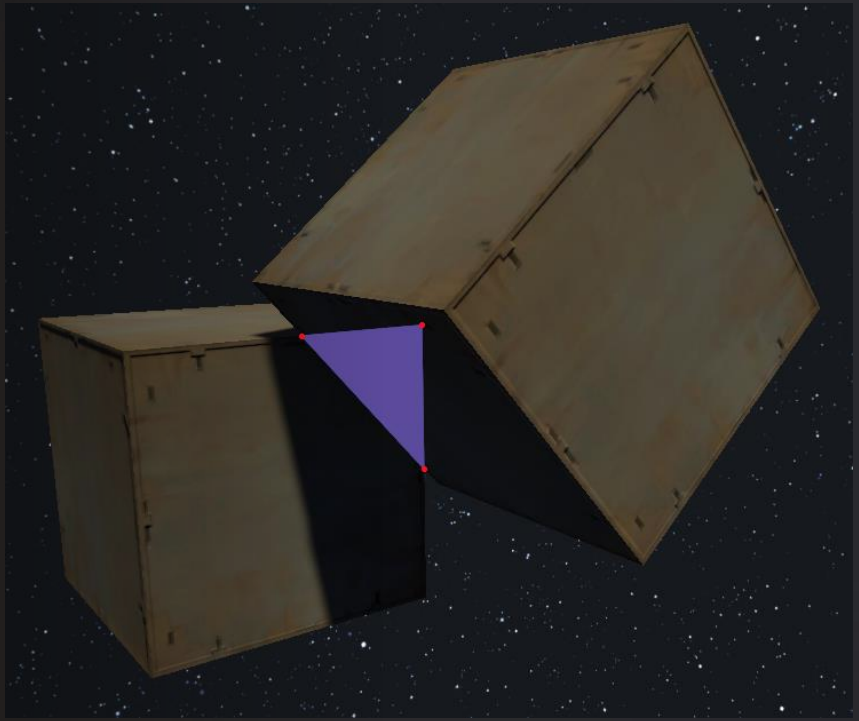
- Find all facing normals
- 2D convex polygons from vertices
- Clip third convex polygon out of overlaps
  - This becomes your Joint Strip!



AUTOMATIC JOINTER V2+

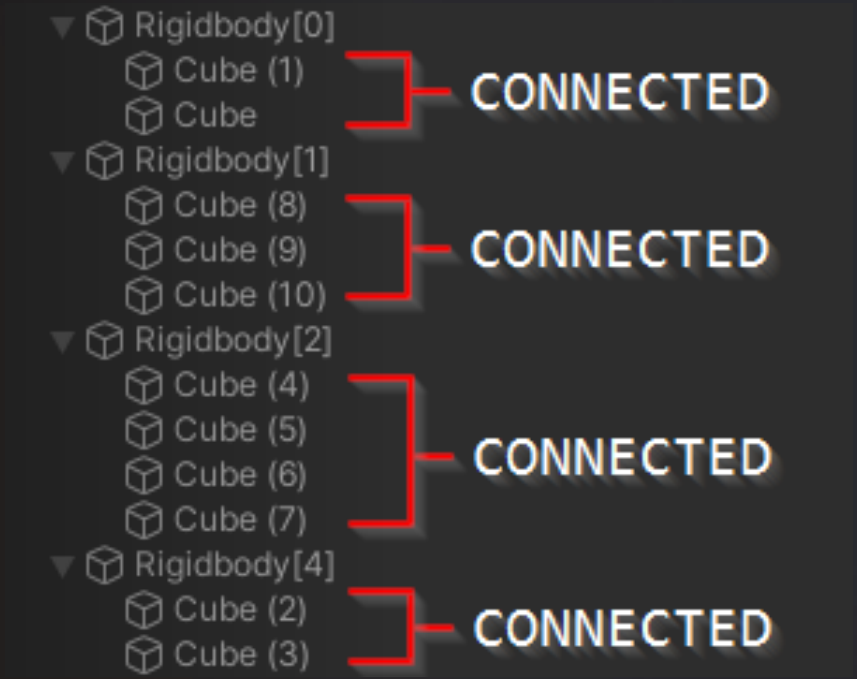
- 2D convex polygons
- Multithreaded & burst compiled!
- 1-10 seconds for the whole ship

Time	Amazing
Accuracy	Amazing
User Error	N/A
Iteration Overhead	N/A
Bulky Data	Better



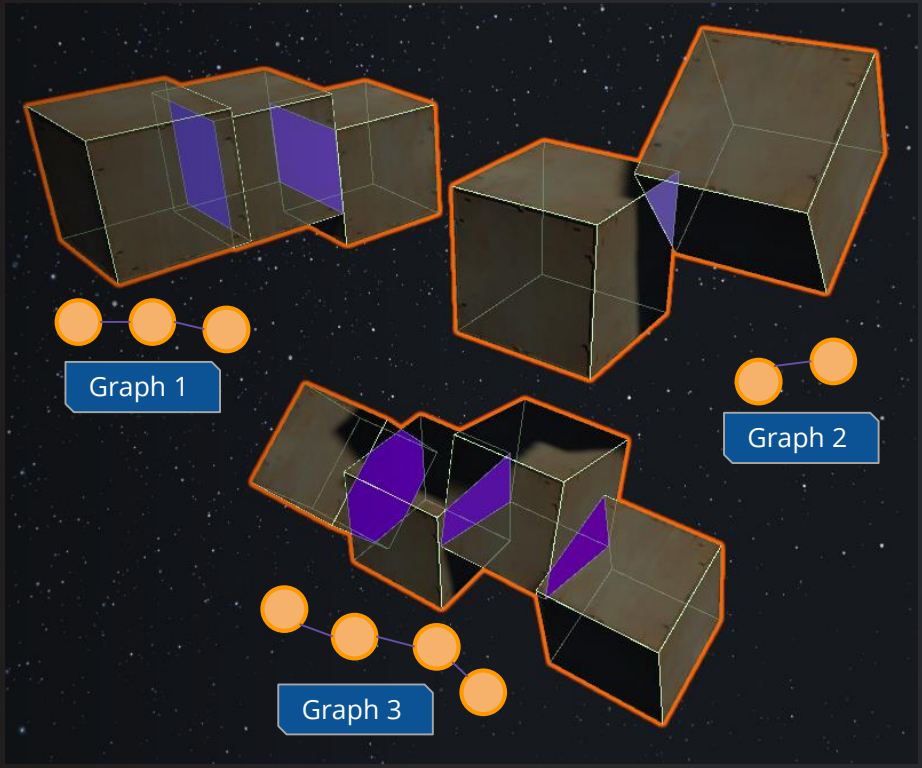
THE HIERARCHY GRAPH

- Joints mean connections!
- Don't rely on physics joints
  - ~ ~ ~ Too jiggly ~ ~ ~
- 1 Rigidbody per group of pieces
  - Mass = sum of pieces



THE HIERARCHY GRAPH

- Graph Data Structure
  - Nodes = pieces
  - Edges = Joints
  - Connected Graph = Rigidbody
- Remove cut pieces/joints from graph
- Add new pieces/joints to graph



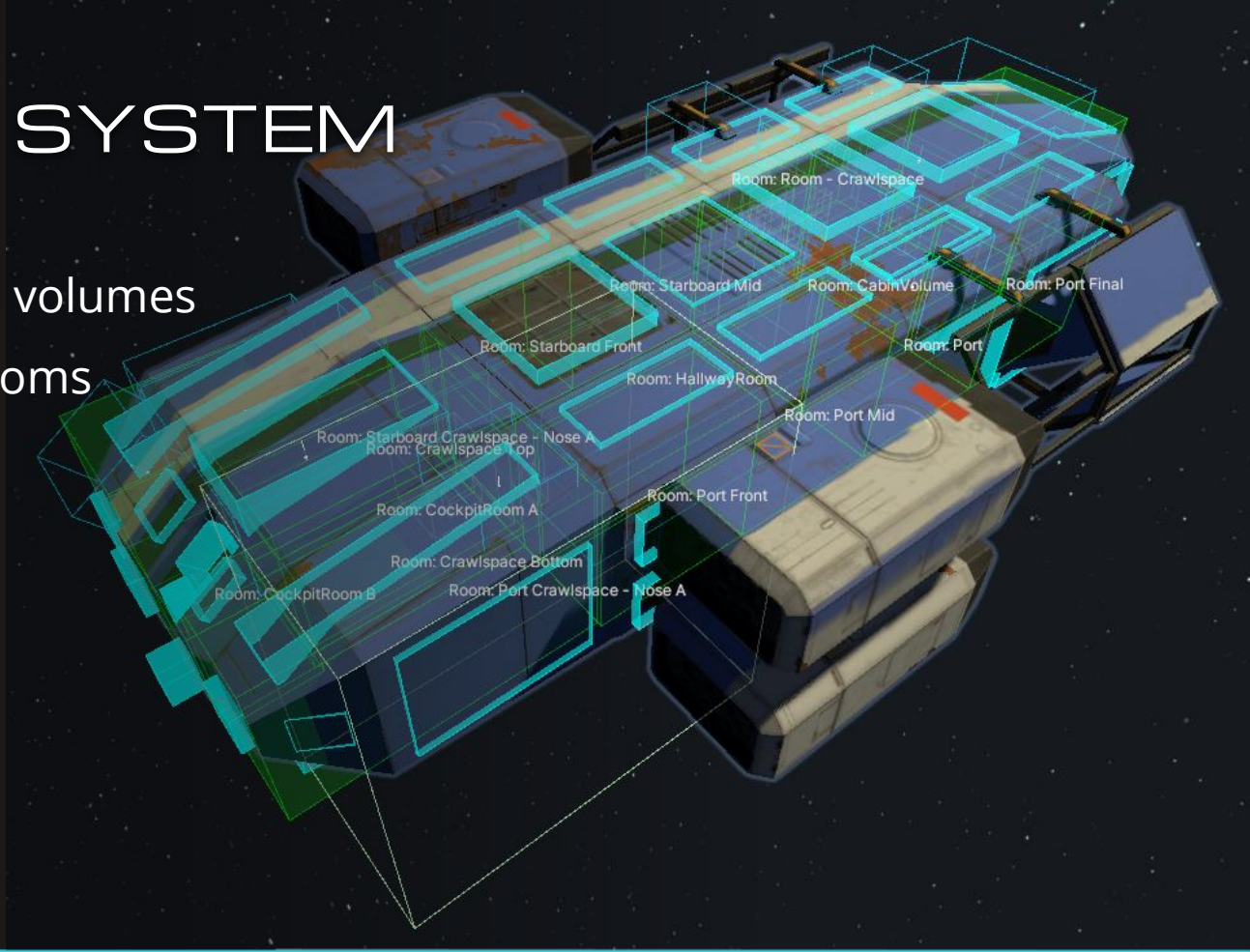
BELIEVABLE INSIDE AND OUT

THE ROOM SYSTEM

- Pressurization
- Metadata
  - Cockpit
  - Crawlspace
  - Etc.
- Tracks the hierarchy

THE ROOM SYSTEM

- Inclusion/Exclusion volumes
- Openings to link rooms
- Sealing pieces



THE ROOM SYSTEM

- Breaches and portals link pressure
- Balanced pressure, safe!
- Different pressure…

THE ROOM SYSTEM

- ...Violent decompressions!
- Air pressure drains through breaches
- Force applied towards breach
- Extra cuts near breach for added chaos

ELEMENTAL CHAIN REACTIONS

THE ELEMENTAL SYSTEM

- Believable elemental interactions
- Inspired by Breath of the Wild's "Chemistry Engine"

THE ELEMENTAL SYSTEM

- Reactionary material properties assigned to all objects
  - Flammable
  - Electrifiable
  - Freezable

THE ELEMENTAL SYSTEM

- Can become actionary properties…
  - Flammable -> Burning
  - Electrifiable -> Electrified
  - Freezable -> Freezing

RESOLVING ELEMENTAL REACTIONS

- Updates must be fast
  - Hundreds of rooms & objects
  - Stored in contiguous memory
  - Multithreaded blocks

INTERCONNECTED SYSTEMS

- Cutter beams are simply burning objects
- No exception cases, just strong ruleset

INTERCONNECTED SYSTEMS

- Explosions are also burning objects
- Also a spherical scatter of cuts
- So many cuts

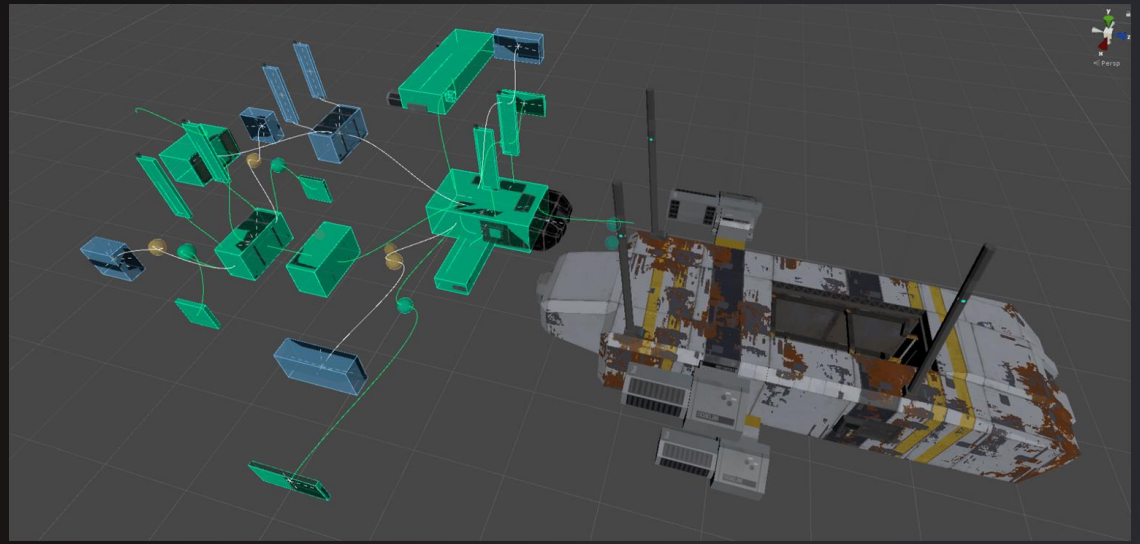
SHIPS THAT BUILD THEMSELVES*

HANDCRAFTED PROCEDURAL

- Runtime Spawning
- Deterministic
- Looks like a spaceship

HANDCRAFTED PROCEDURAL

- Designers create ship blueprints
- Defines the shape and branching possibilities!

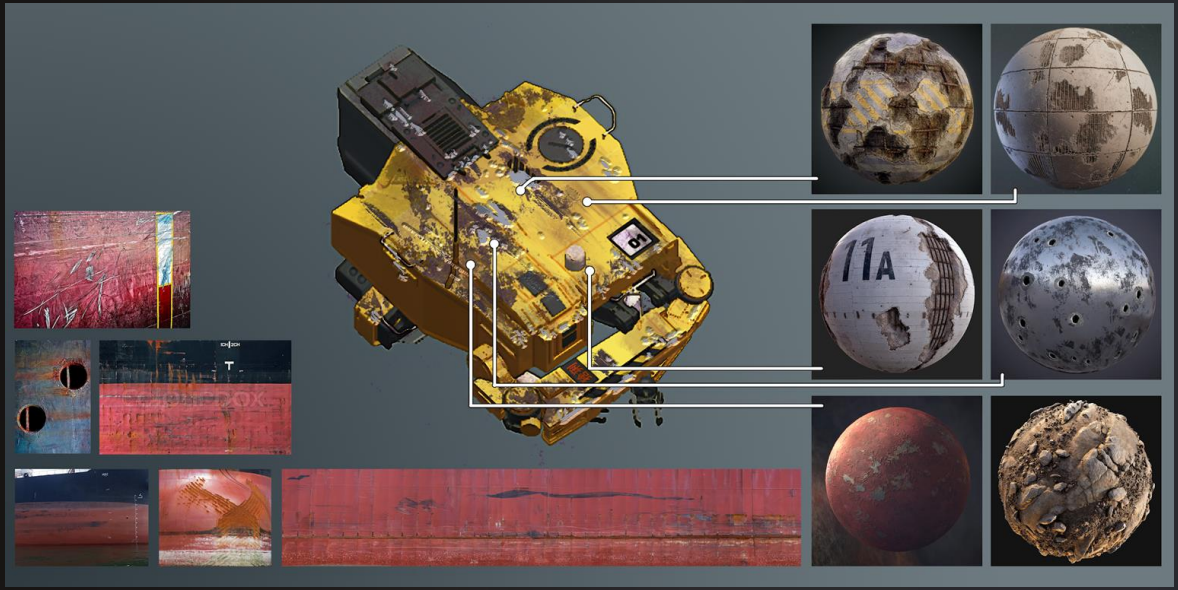


HANDCRAFTED PROCEDURAL

- Nested randomization
  - Objects spawn from hardpoints
  - Spawned objects have more hardpoints
  - Weighted values for curated randomization

HANDCRAFTED PROCEDURAL

- Dynamic paint jobs
  - Triplanar mapping
- Procedural dirt
  - 3D noise map



HANDCRAFTED PROCEDURAL

TO RECAP...

THE RESULTS

- Meshes can be split from any angle
- Mesh guts can be generated
- Pieces can be held together by tape
- Ships are glorified graphs
- Rooms are linked by boxes
- Fire is dangerous
- A lot goes into making ships that build themselves*!

THANK YOU!

HARDSPACE
SHIPBREAKER

Richard Harrison
Technical Director

richard.harrison@blackbirdinteractive.com

BLACKBIRD INTERACTIVE