OpenVDB in Houdini

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SIDE EFFECTS SOFTWARE

Houdini

- Node-based, procedural 3D modelling, animation, and visual effects software
- Built-in dynamics solvers
- Volume simulation and rendering

SIDE EFFECTS SOFTWARE

Projects

- FLIP liquid solver
- Whitewater solver
- OceanFX toolkit
- OpenCL-accelerated Pyro solver
- POP and Grain solvers
- Geometric and dynamic fracturing

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OpenVDB in Houdini

- First introduced in 12.5
- Integration with Houdini volume toolset
- Conversion to and from native volumes
  - 16^3 voxel tiles
  - Constant tile optimization
- VEX and Mantra support for VDB Volumes
- VDB specific SOPs from OpenVDB team
- Siggraph 2013 Course Slides
  - openvdb.org

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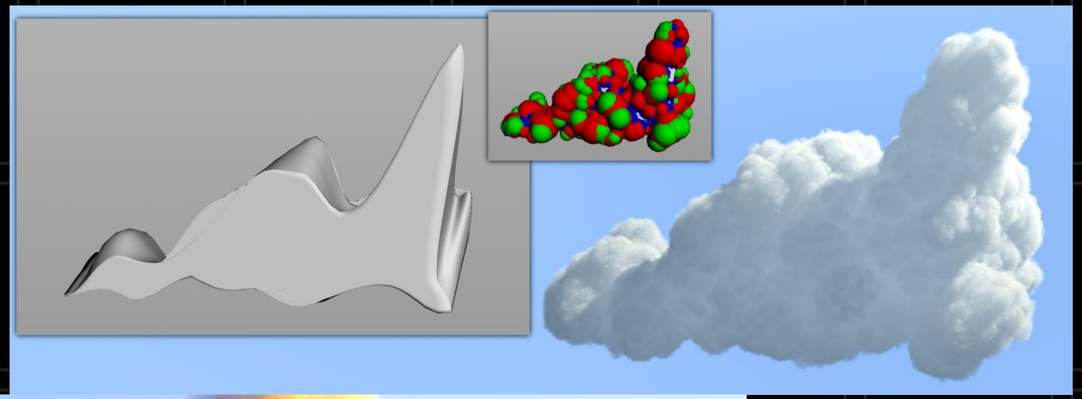
Higher Level OpenVDB Tools
Clouds and Grooming



- Introduced in Houdini 13 and 14
- Shape construction
- Noise modulation
- Advection
- Rendering

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Higher Level OpenVDB Tools
Fluid and Grain Solvers

- Introduced in Houdini 14 and 15
- VDB operations throughout
- Sourcing data for simulation
- Accelerating simulation
- Post-processing simulation data

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Higher Level OpenVDB Tools Overview

- SDF Collisions
- Accelerated Point Lookup
- FLIP Data Compression
- Sparse Points From Volume
- Fluid Surfacing

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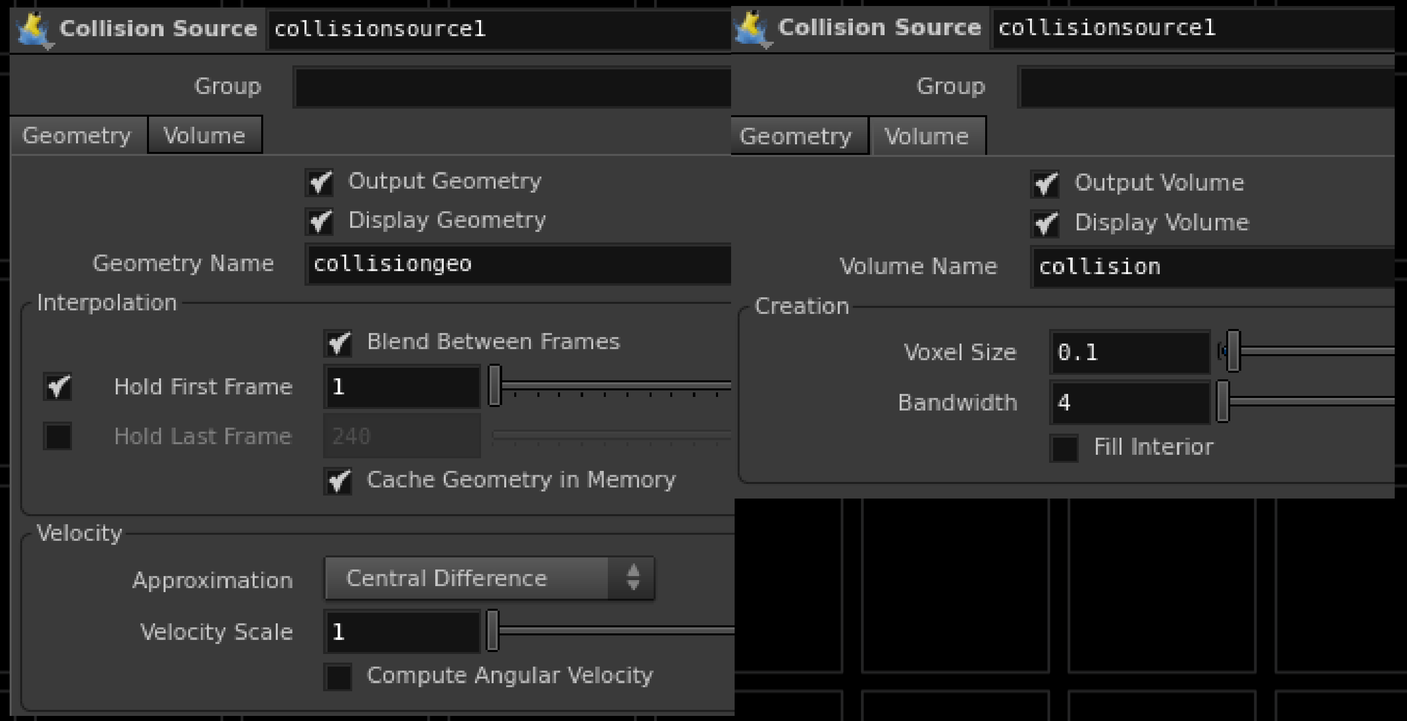
SDF Collisions

- Deforming Object shelf tool
- Point velocities on geometry
- Collision SDF with VDB From Polygons
- Cached to disk at substeps

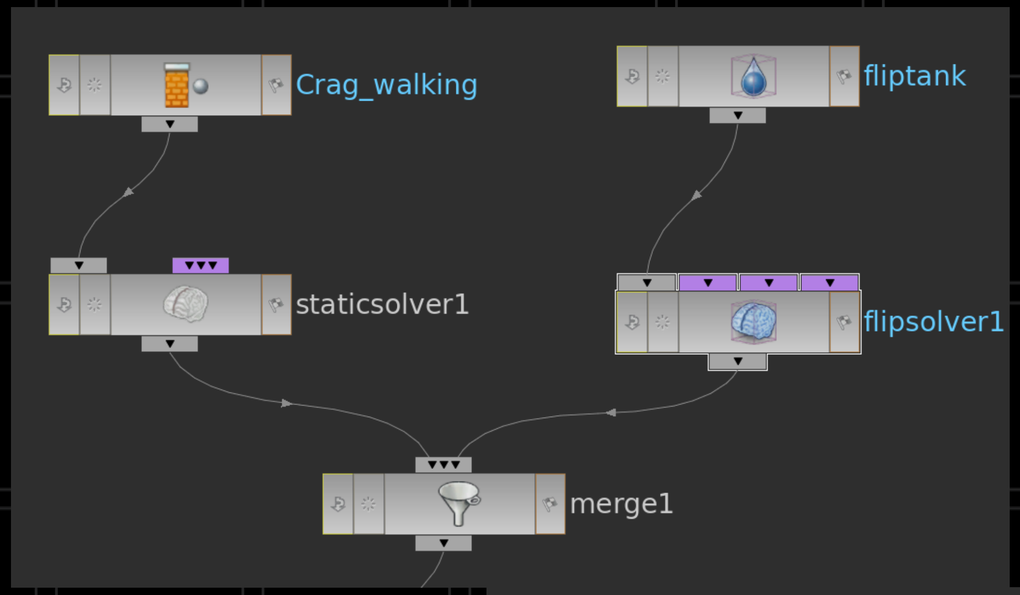


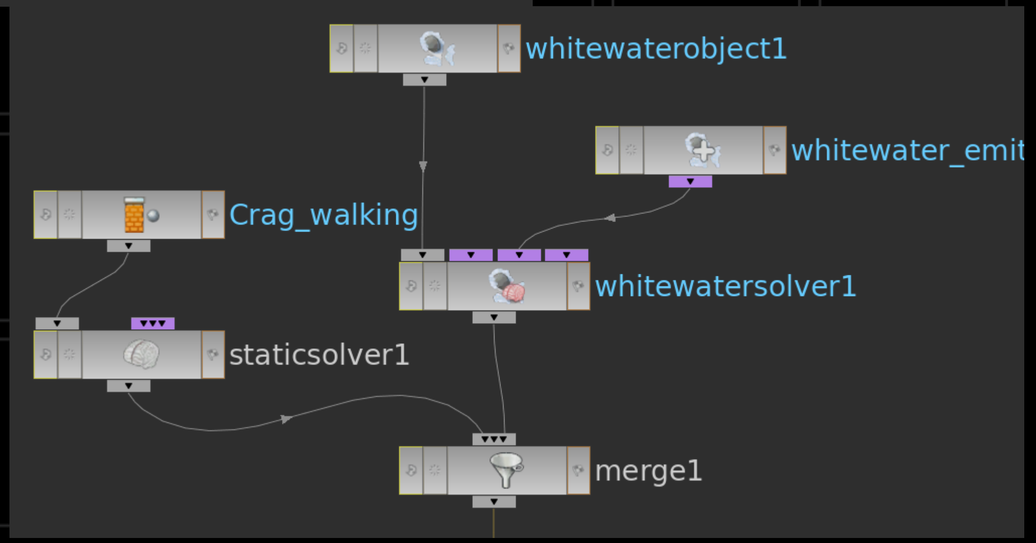
SIDE EFFECTS SOFTWARE

SDF Collisions

- Standard collision tool across solvers
  - Point / SDF collisions
  - Voxel weights in variational pressure solve for FLIP

- SDF often re-used downstream
  - Secondary element collisions
  - Boolean operations
  - Particle activation

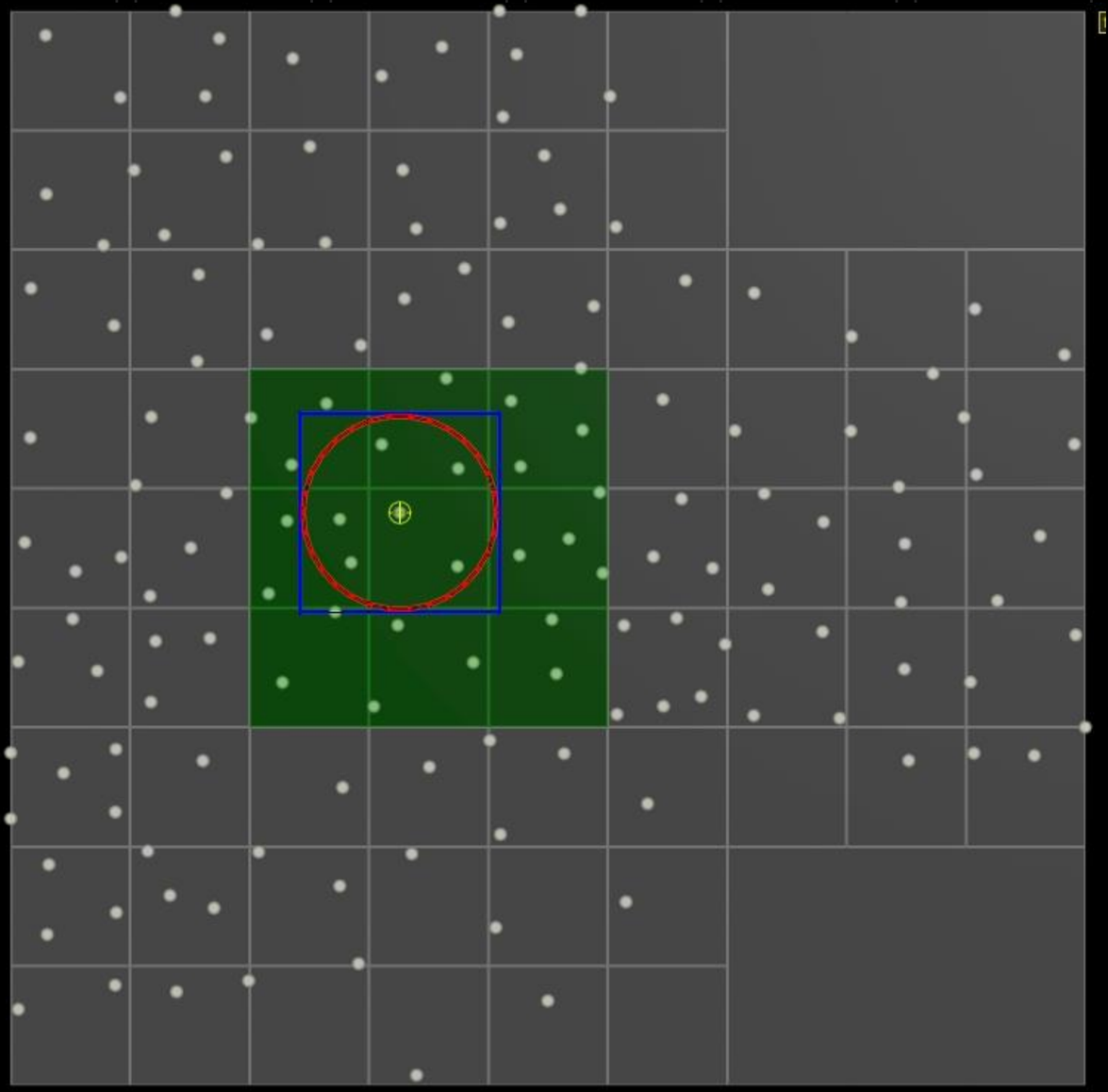




SIDE EFFECTS SOFTWARE

Accelerated Point Lookup
Point Index Grid

- Partition points into voxels
  - Uses Point Partitioner under the hood
- Store point indices in voxels
- Query arbitrary position against uniform radius particles
- Constant-time query returns iterator over particles in touched voxels
  - Deterministic but not sorted
- Fast and memory efficient
- “Gather” operation



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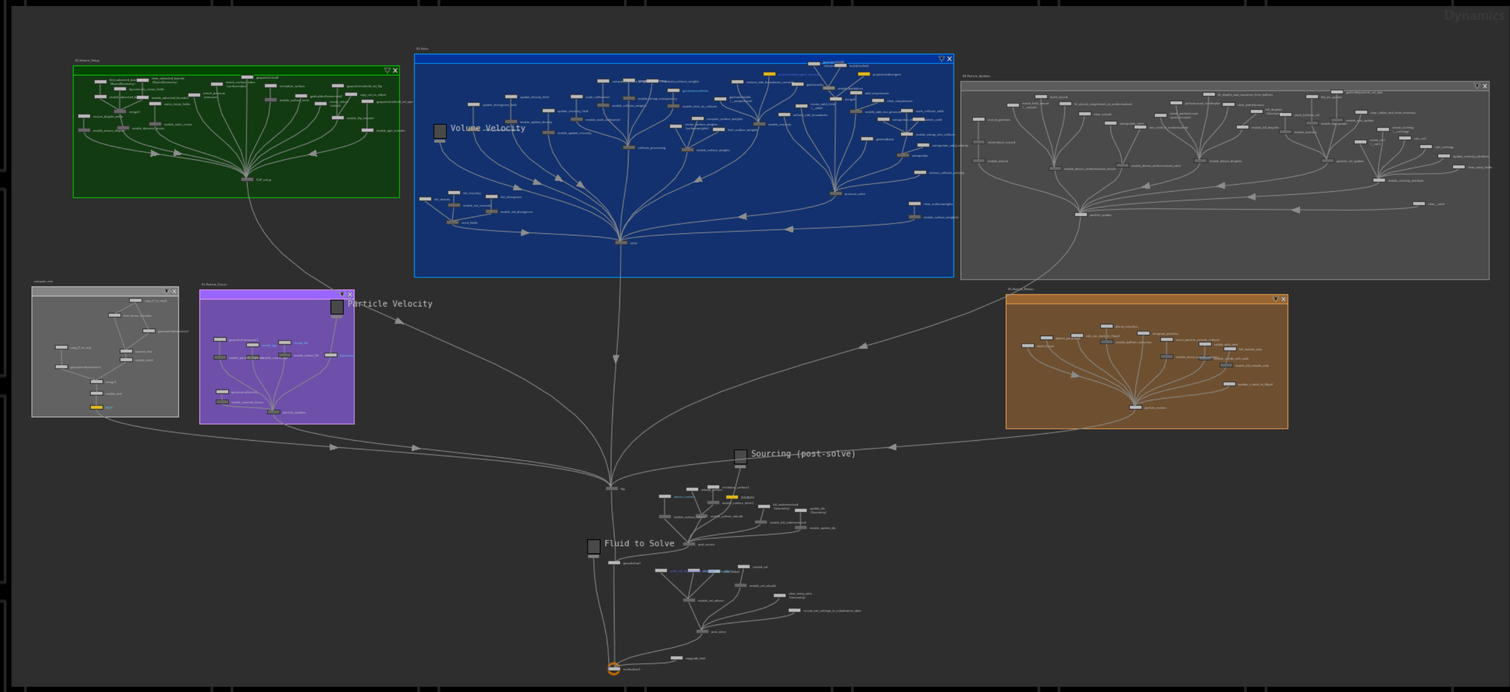
Accelerated Point Lookup
FLIP Solver Operations

- Transfer particle velocity to simulation field
  - Gas Particle To Field DOP
- Build SDF representing fluid surface
  - Gas Particle To SDF DOP
- Calculate particle density in voxel
  - Gas Particle Count DOP
- Reseed voxels with too few / many particles
  - Gas Seed Markers DOP



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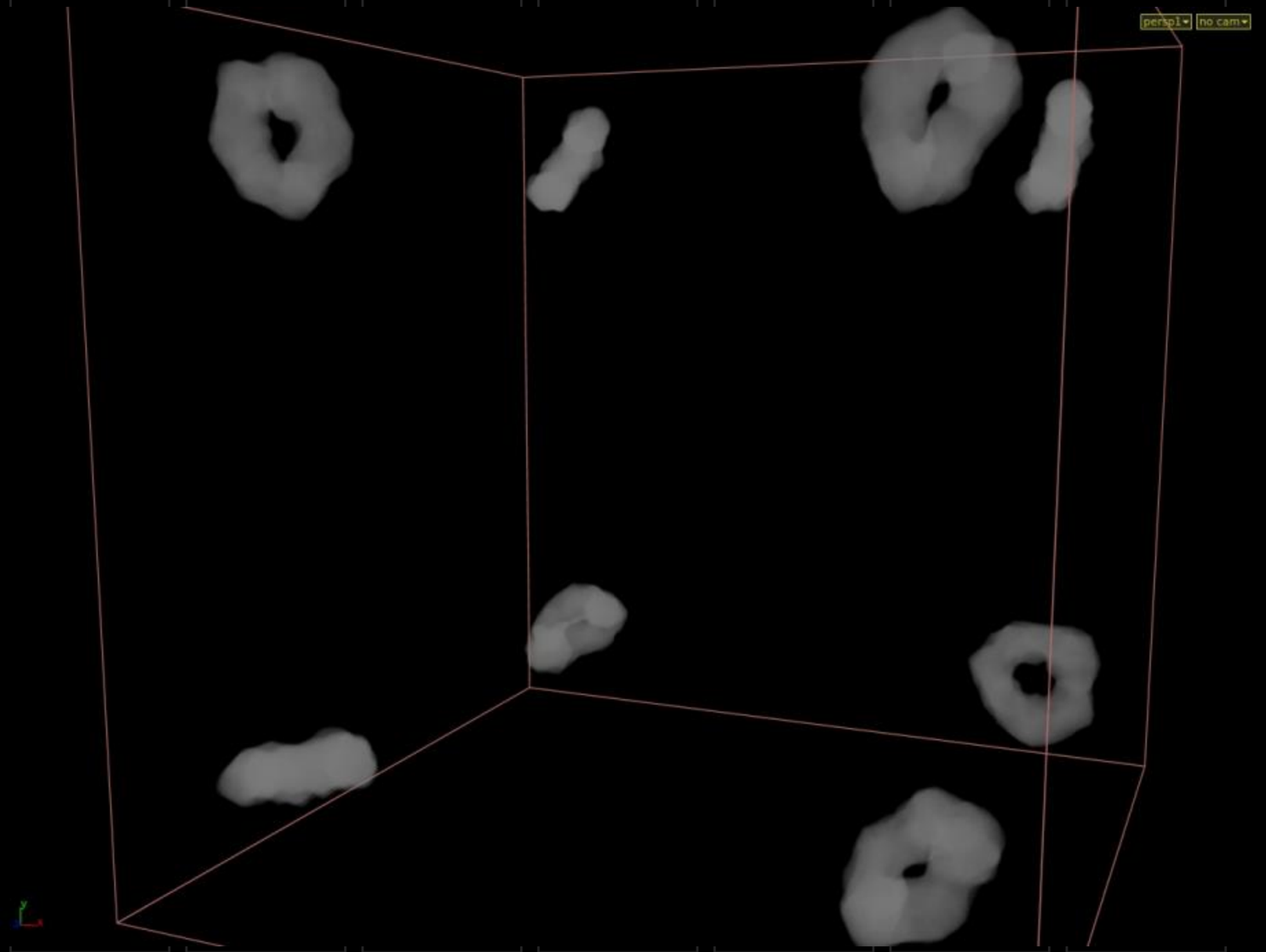
Accelerated Point Lookup Comparison to UT_PointGrid

- Transfer velocity attribute to face-sampled vector field
- Dense configuration has all points at center
- Medium test is 93M points and 1200^3 voxels



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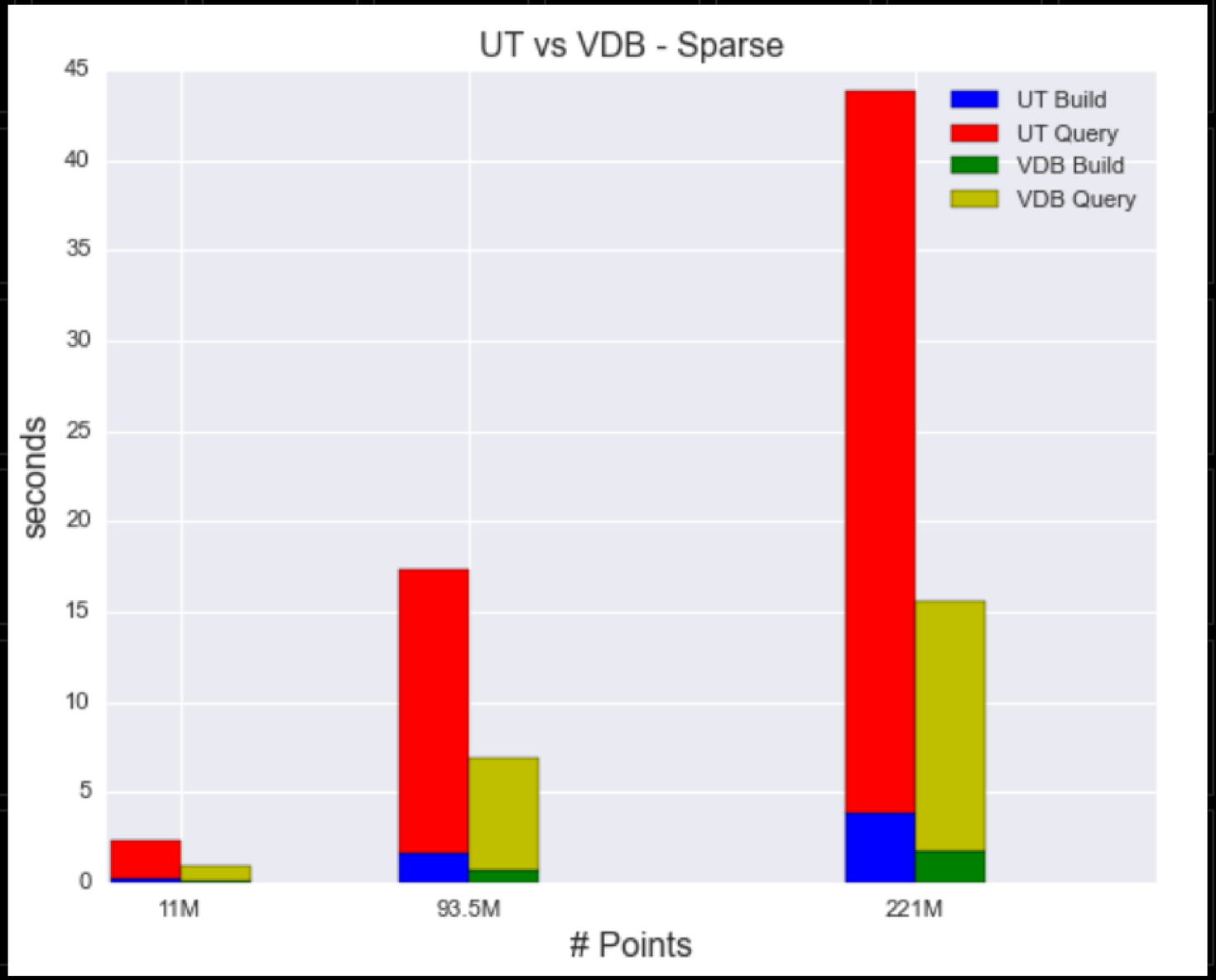
Accelerated Point Lookup Sparse Performance

- 2 – 3X faster for sparse configurations
- 1 min / frame improvement at 220M particles and 2 substeps
- Additional gains from other point lookup operations



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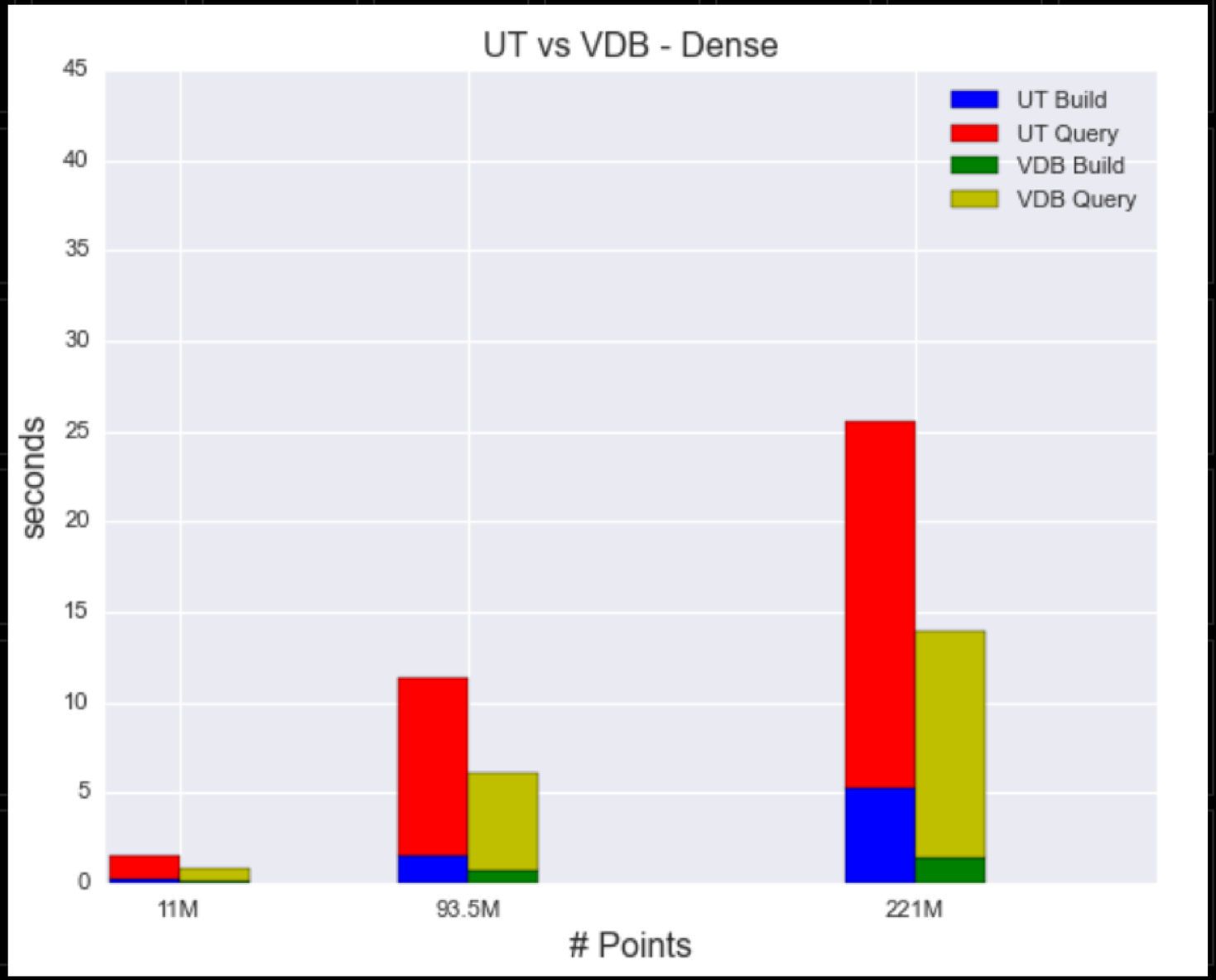
Accelerated Point Lookup Dense Performance

- Almost 2X faster even for dense configurations
- Small difference in sparse vs dense for VDB



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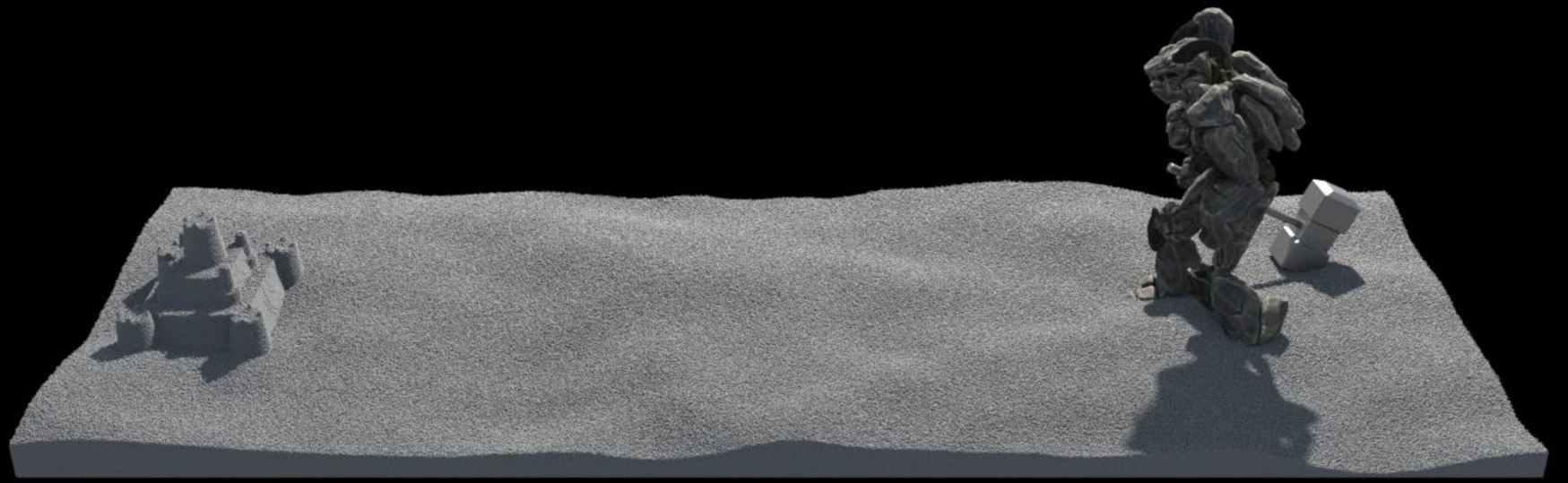
Accelerated Point Lookup
PBD-based Grain Solver

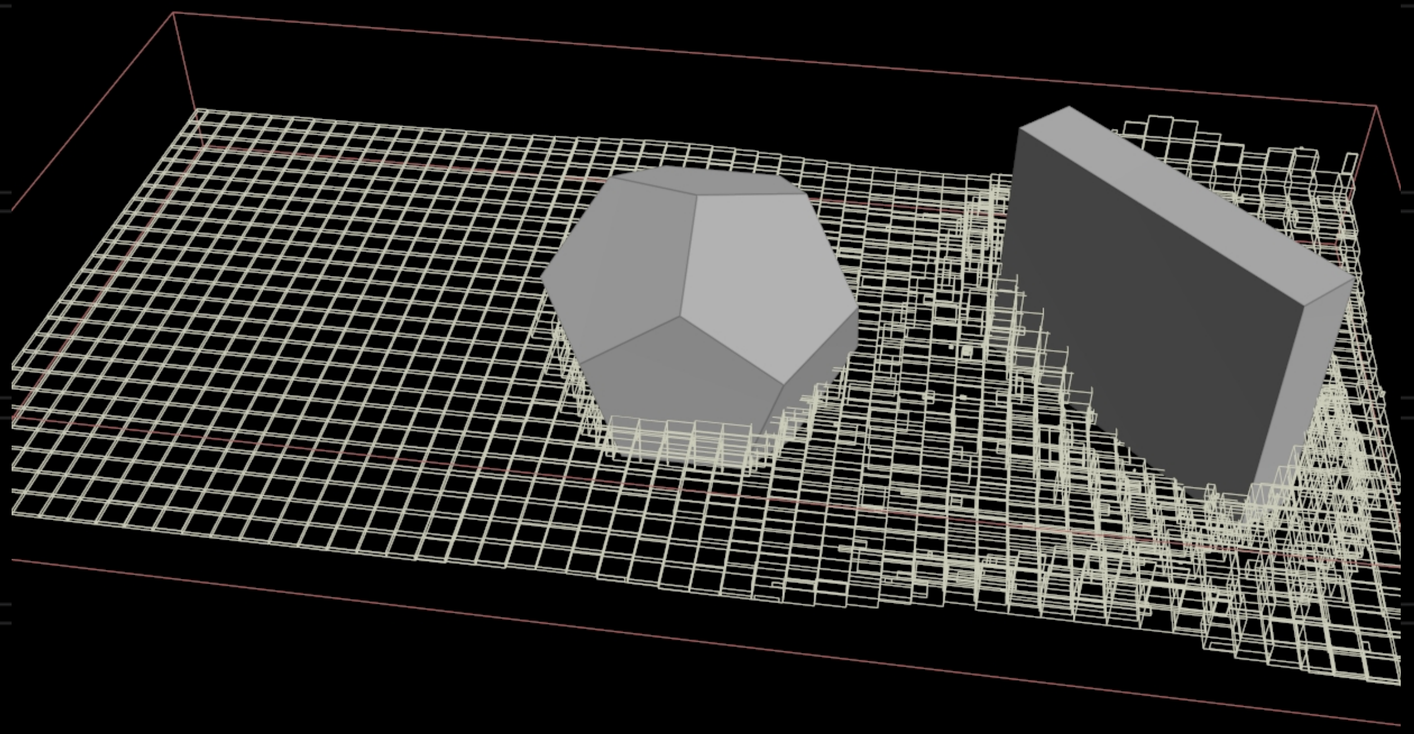
- VDB collisions
- `pgfind` for neighbor lookup
  - Spatial lookup on CPU
  - Constraint loop on GPU
- VDB-based sandbox generation
- VDB-based particle activation



SIDE EFFECTS SOFTWARE

FLIP Data Compression

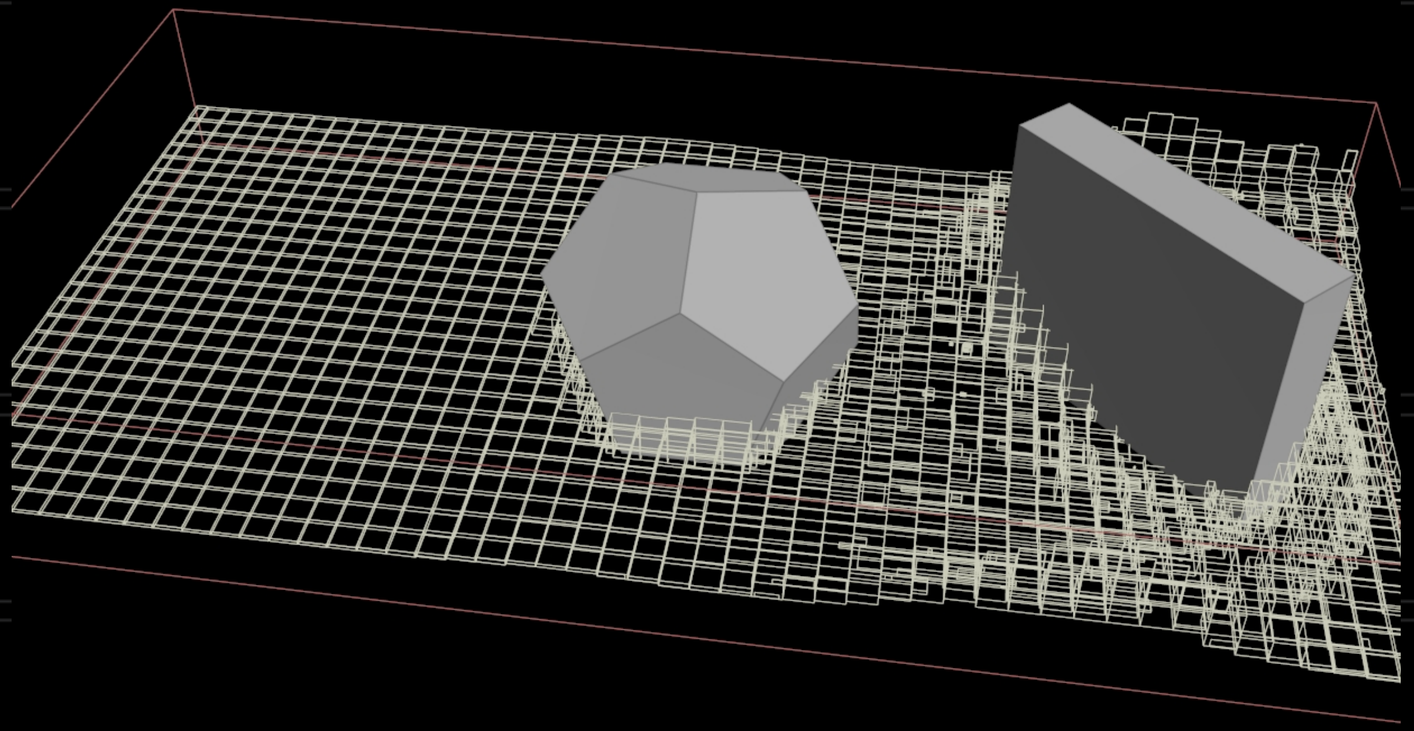
- New in Houdini 15
- 100’s of millions of particles common
  - Especially when distributed!
- Large disk space requirements
- High network load



SIDE EFFECTS SOFTWARE

FLIP Data Compression

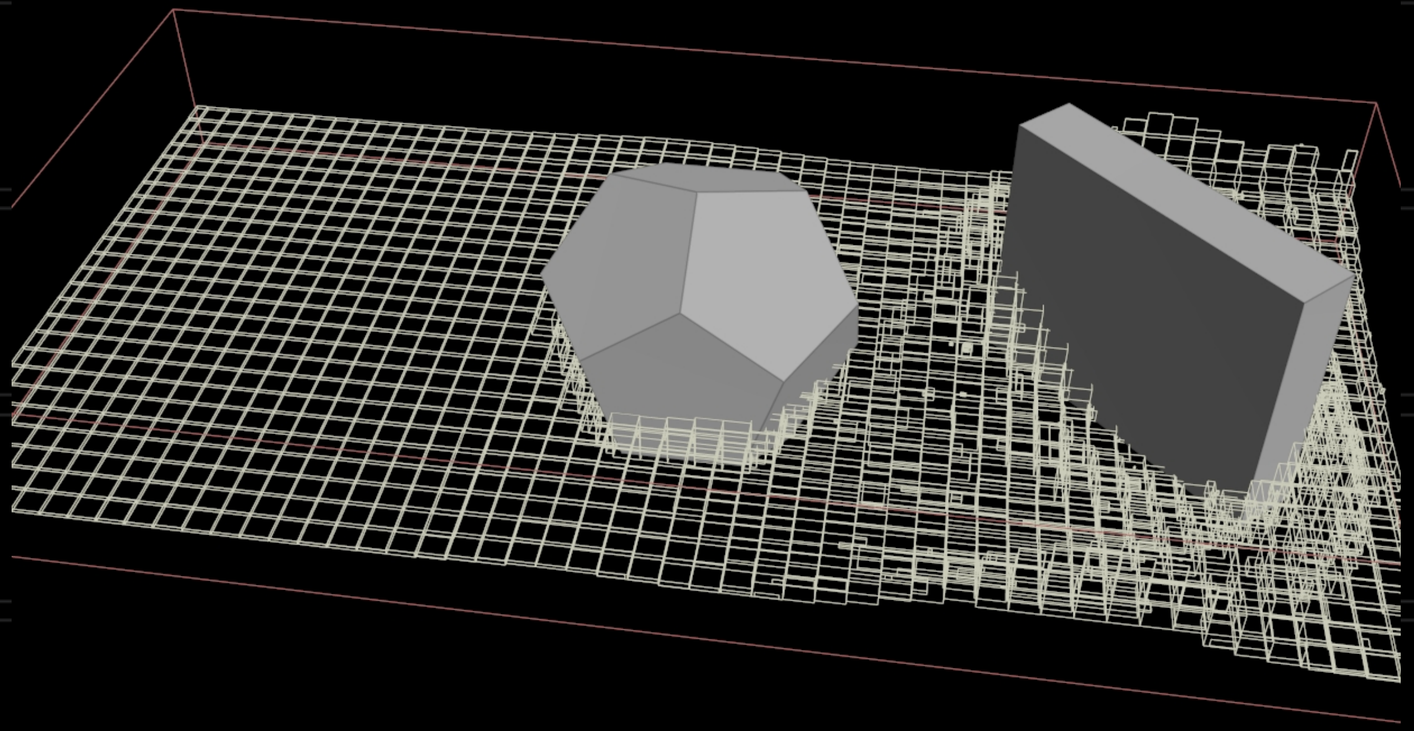
- Dense, native simulation data
- Sparse data as lossy post-process



SIDE EFFECTS SOFTWARE

FLIP Data Compression

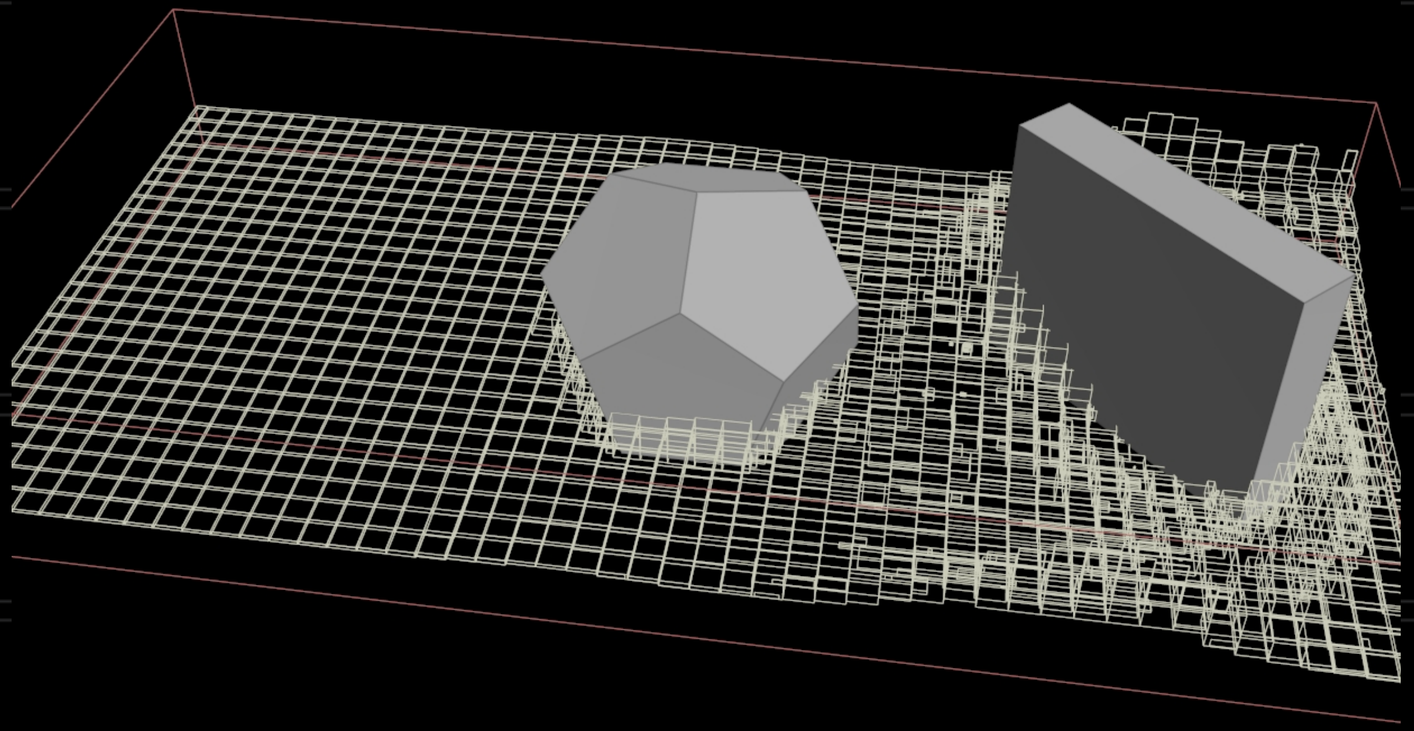
- Dense, native simulation data
- Sparse data as lossy post-process
- FLIP Particles
  - Primary simulation representation
    - Marker particles
    - Velocity and other attributes
  - ***Surface detail***



SIDE EFFECTS SOFTWARE

FLIP Data Compression

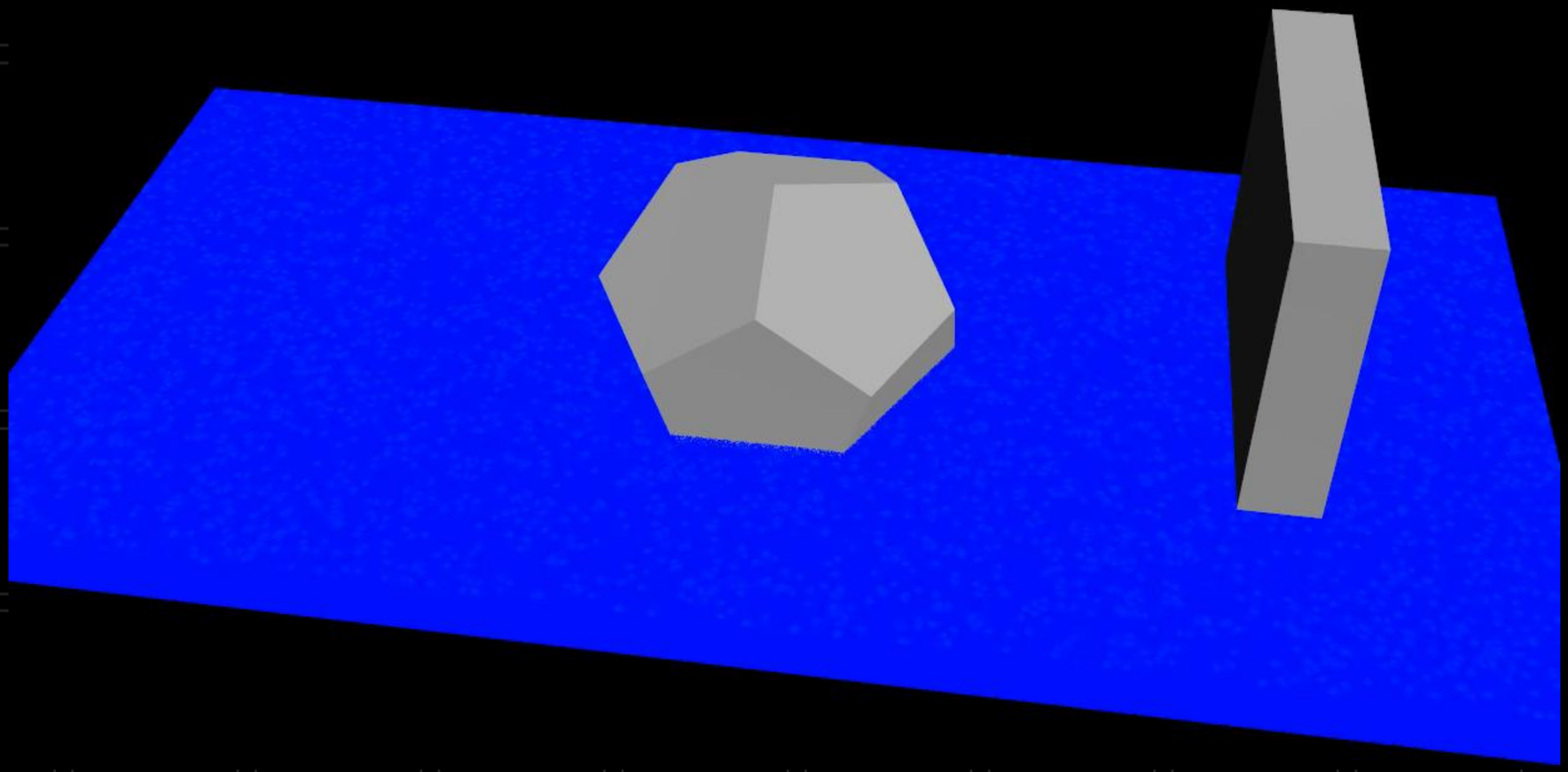
- Dense, native simulation data
- Sparse data as lossy post-process
- FLIP Particles
  - Primary simulation representation
    - Marker particles
    - Velocity and other attributes
  - ***Surface detail***
- Surface SDF and velocity volumes
  - Secondary simulation representation
  - FLIP pressure solve and advection
  - Secondary elements
    - Emission
    - Depth testing
    - Advection
  - ***Fluid data “decompression”***



SIDE EFFECTS SOFTWARE

FLIP Data Compression Example

- Uncompressed dense data set
- 11M Particles
  - Tiny!
- 14M voxels in surface and vel
- 52 Gb for 240 frames
  - Blosc compressed
- Playback 3.2 sec / frame



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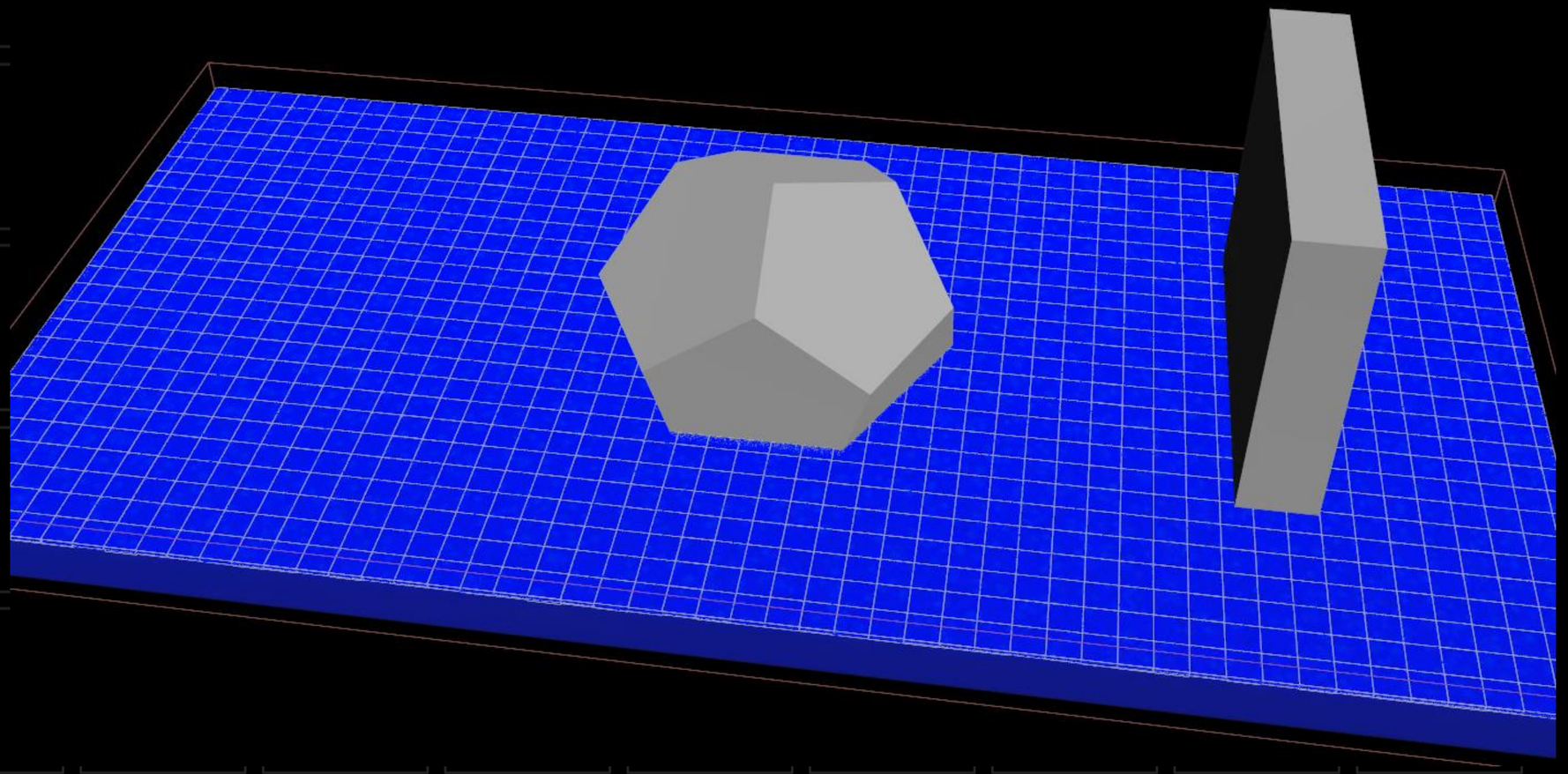
FLIP Data Compression Example

- Lossy-compressed data set
  - 1.3M particles (8x)
  - 7M 16-bit voxels (4x)
- 8.5 Gb on disk (6x overall)
- Playback 300 ms / frame (10x)
  - Scrubbable
- Higher res / deeper = better ratios
  - 1B particles at 1.5 bytes per



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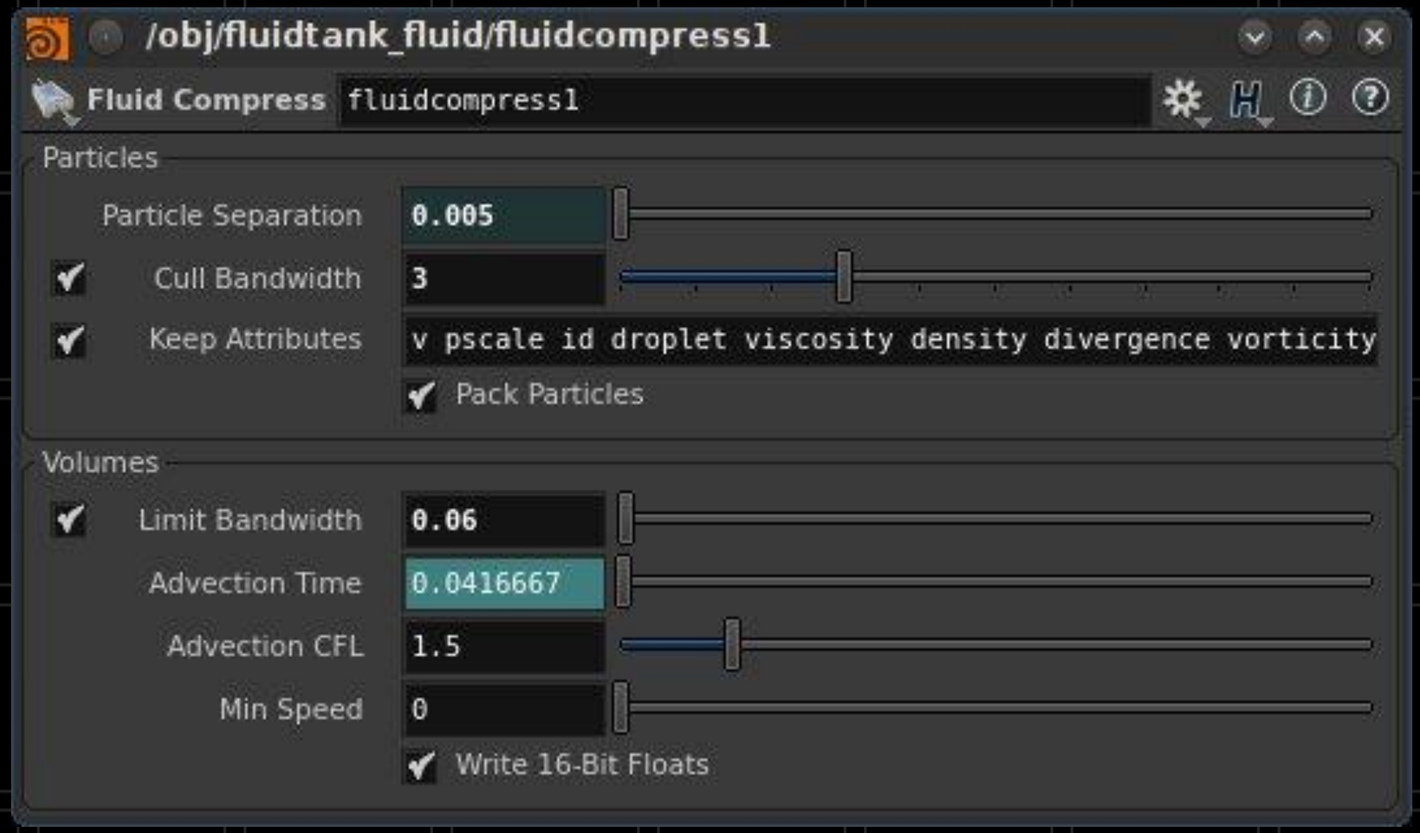
FLIP Data Compression Steps

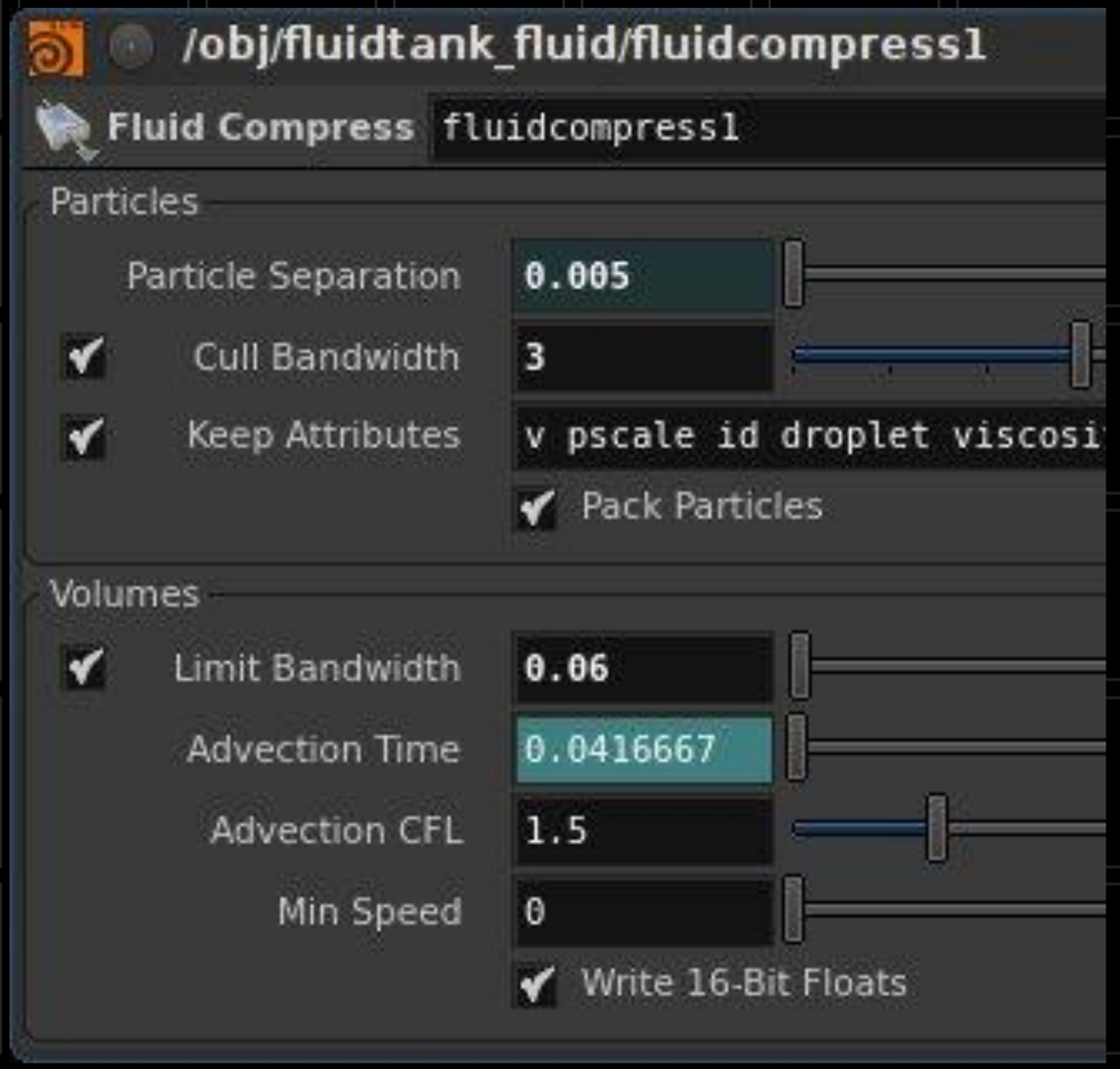
- Points
  - Cull by depth
  - Spatially partition into 4K tiles with VDB's Point Partitioner
  - Create packed primitive per tile
  - Delay Load



SIDE EFFECTS SOFTWARE

FLIP Data Compression Steps

- Volumes
  - Native surface volume to narrow-band VDB
  - Zero velocity field by backwards advection and convert to VDB
  - Prune inactive voxels
  - Save as 16-bit floats
- Output packed particles + surface and velocity VDBs



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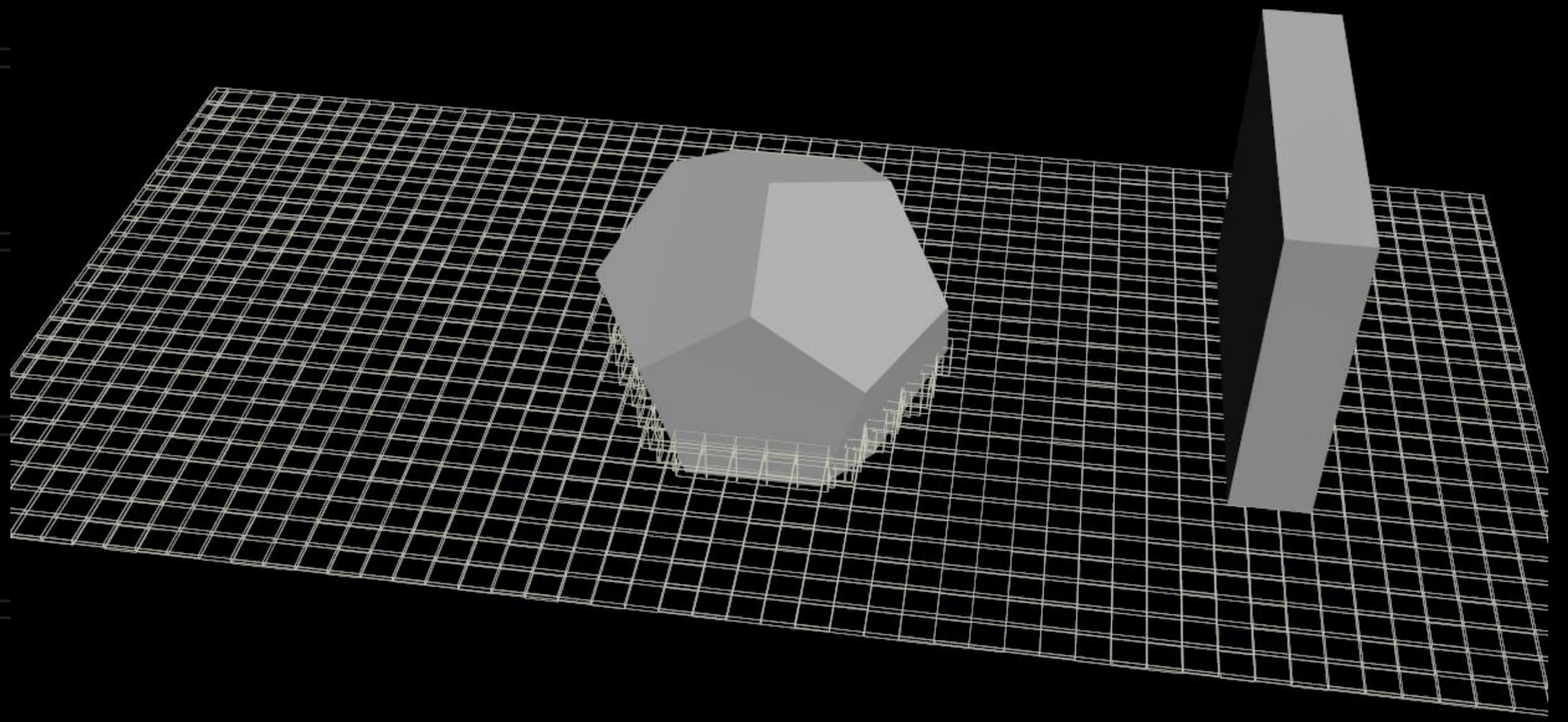
FLIP Data Compression
Compressed Output

- 2K tiled Packed Primitives
- 300 ms / frame playback



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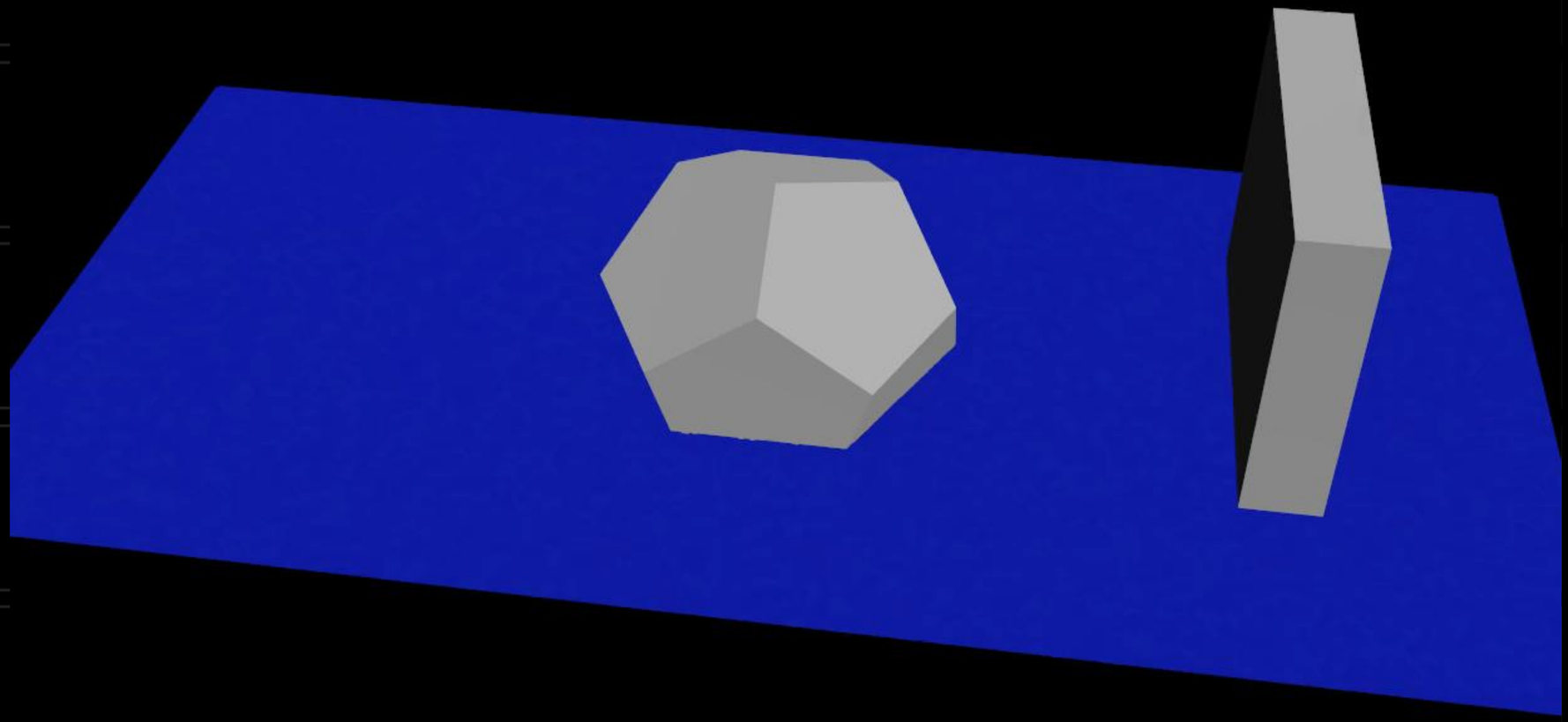
FLIP Data Compression
Delayed Loading

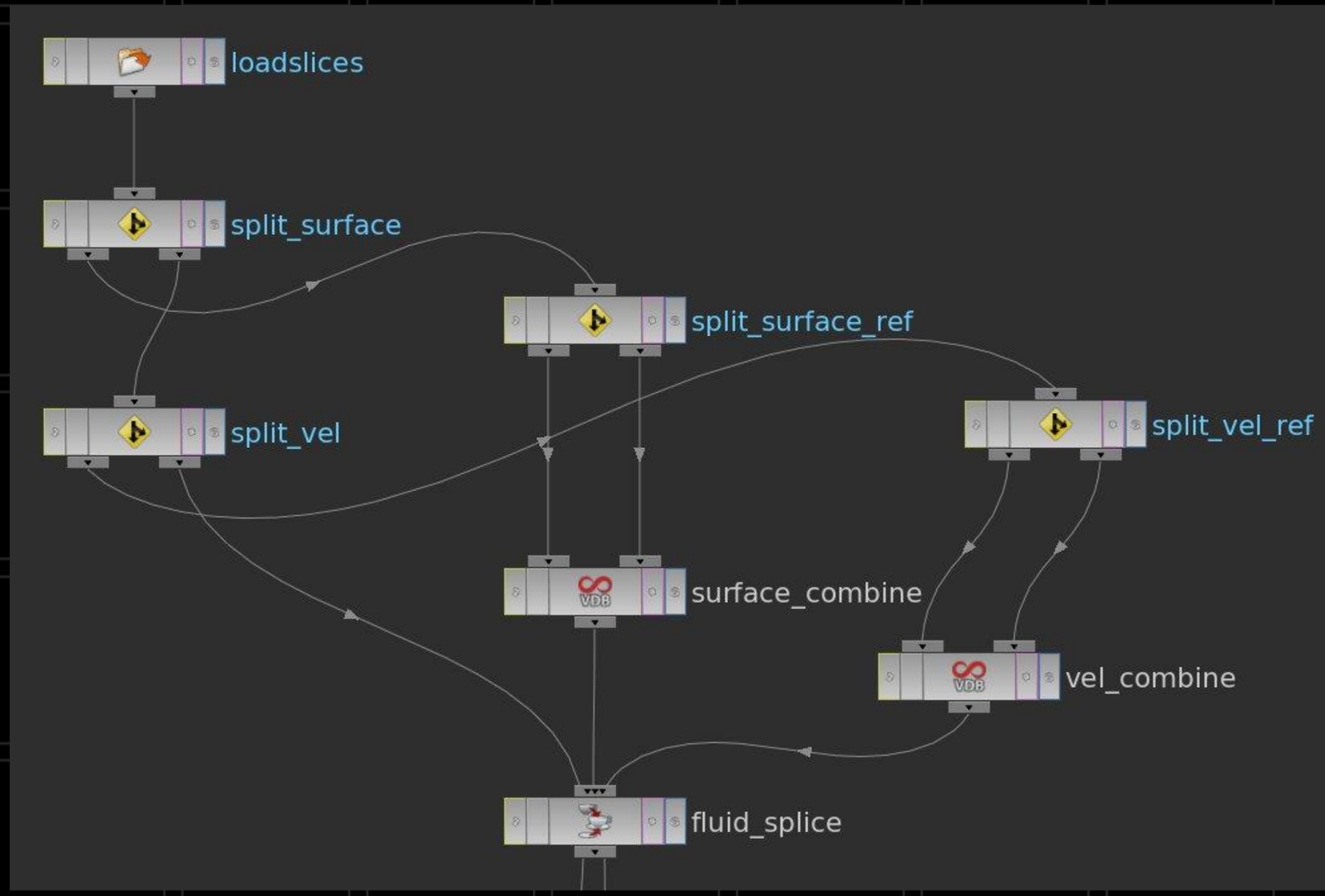
- Meshed narrow-band surface and velocity VDBs
- Points never load from disk
- 400 ms / frame playback
- VDB meshing and volume sampling



SIDE EFFECTS SOFTWARE

FLIP Data Compression
Merge Distributed Slices

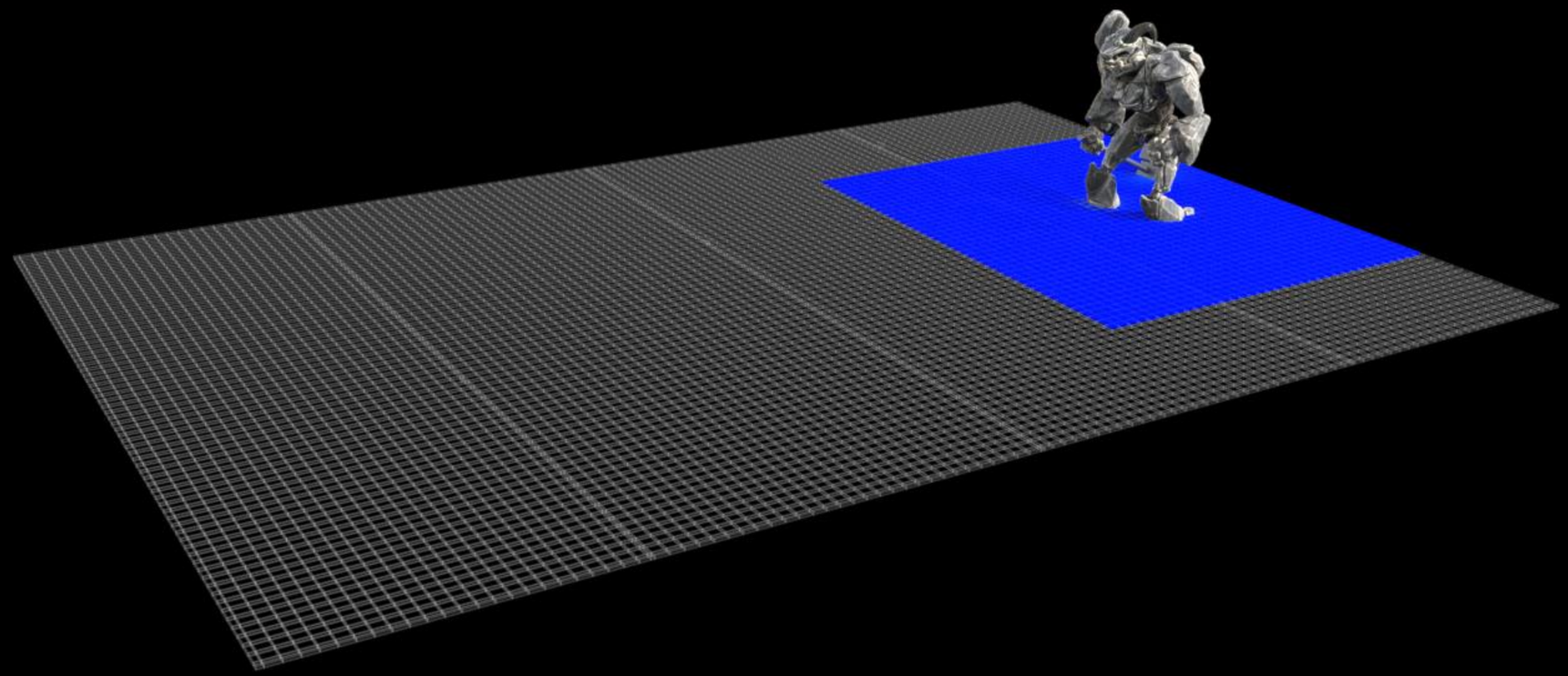
- Compressed FLIP data from several nodes
- Splice together for downstream operations
- On save
  - Delete particles outside slice
  - Compress fluid
  - Zero and de-activate velocity
- On load
  - Merge particles
  - Union all surface SDFs
  - Combine all active regions of velocity
  - “Flatten All B into A”



SIDE EFFECTS SOFTWARE

FLIP Data Compression
Load by Region

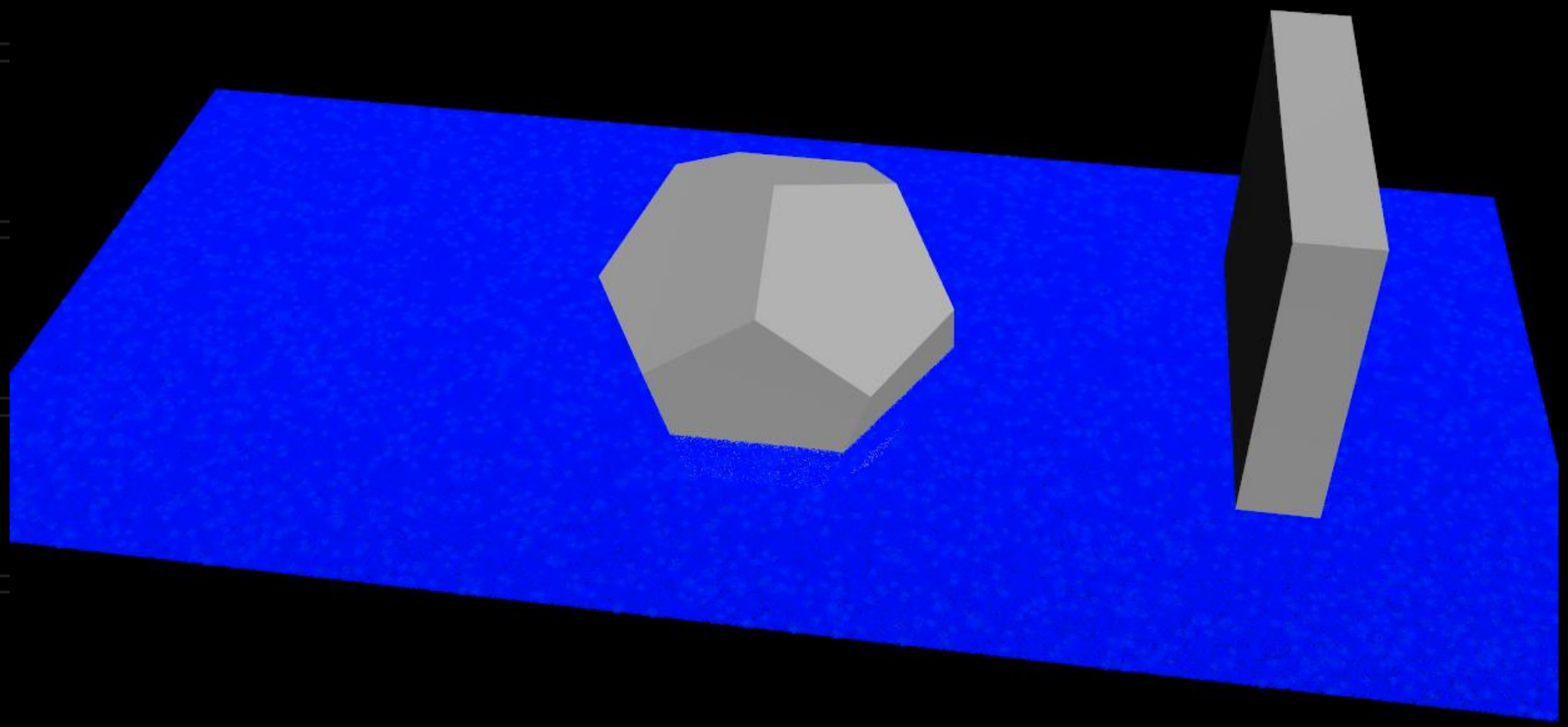
- 120M particle distributed sim
- ~12M particles compressed
- Spatial partition allows restricting loading to region
  - Bounding box
  - Camera
- Tune secondary elements
- Iterate over surfacing



SIDE EFFECTS SOFTWARE

FLIP Data Compression
Where Are All My Particles?

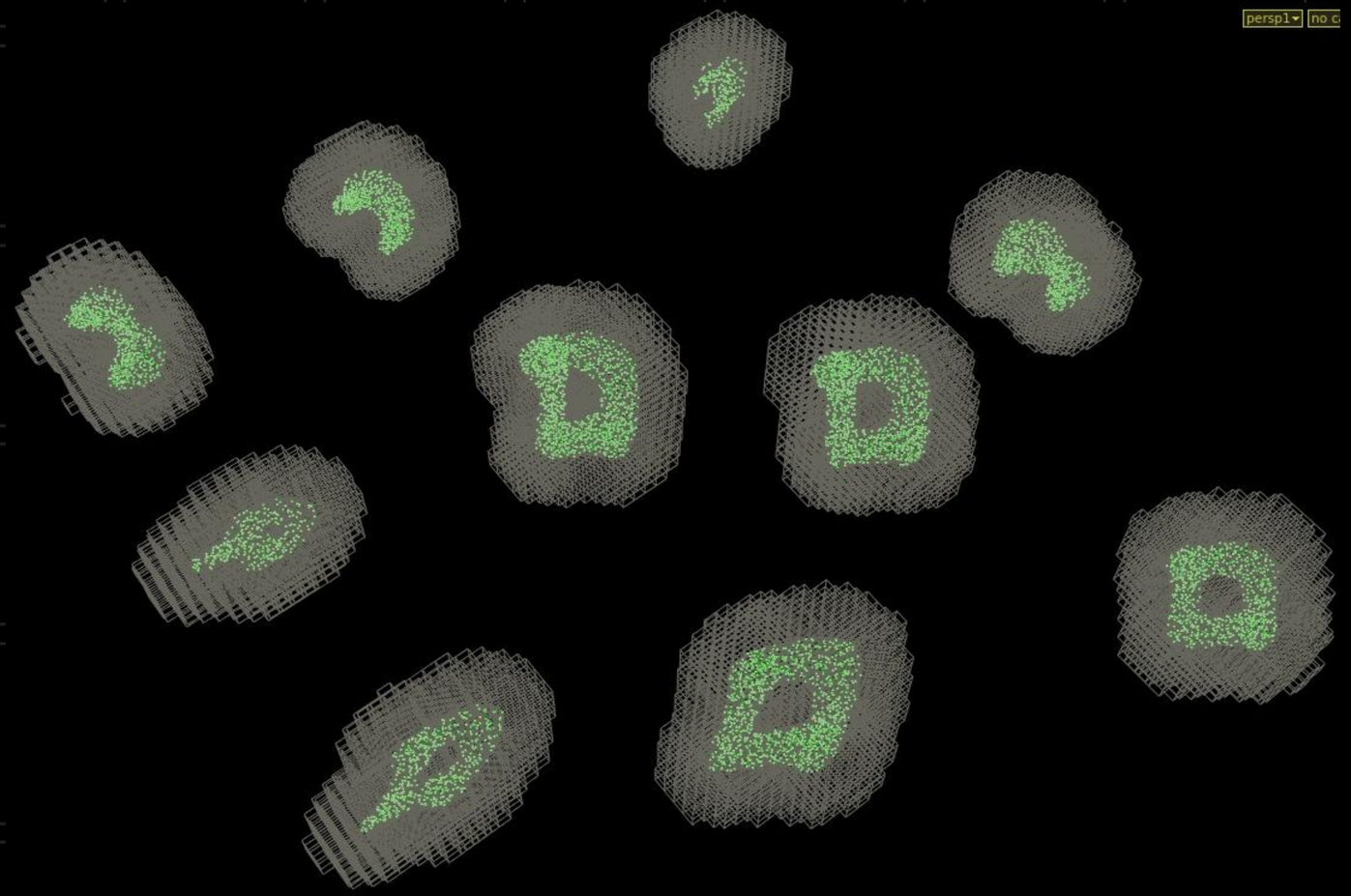
- Thin particle layer
- 700 ms / frame playback
- Deep secondary elements?
  - Aeration
  - Bubbles
- Surfacing?
- Reseed points with velocity anywhere within fluid



SIDE EFFECTS SOFTWARE

Sparse Points From Volume Algorithm (VDB)

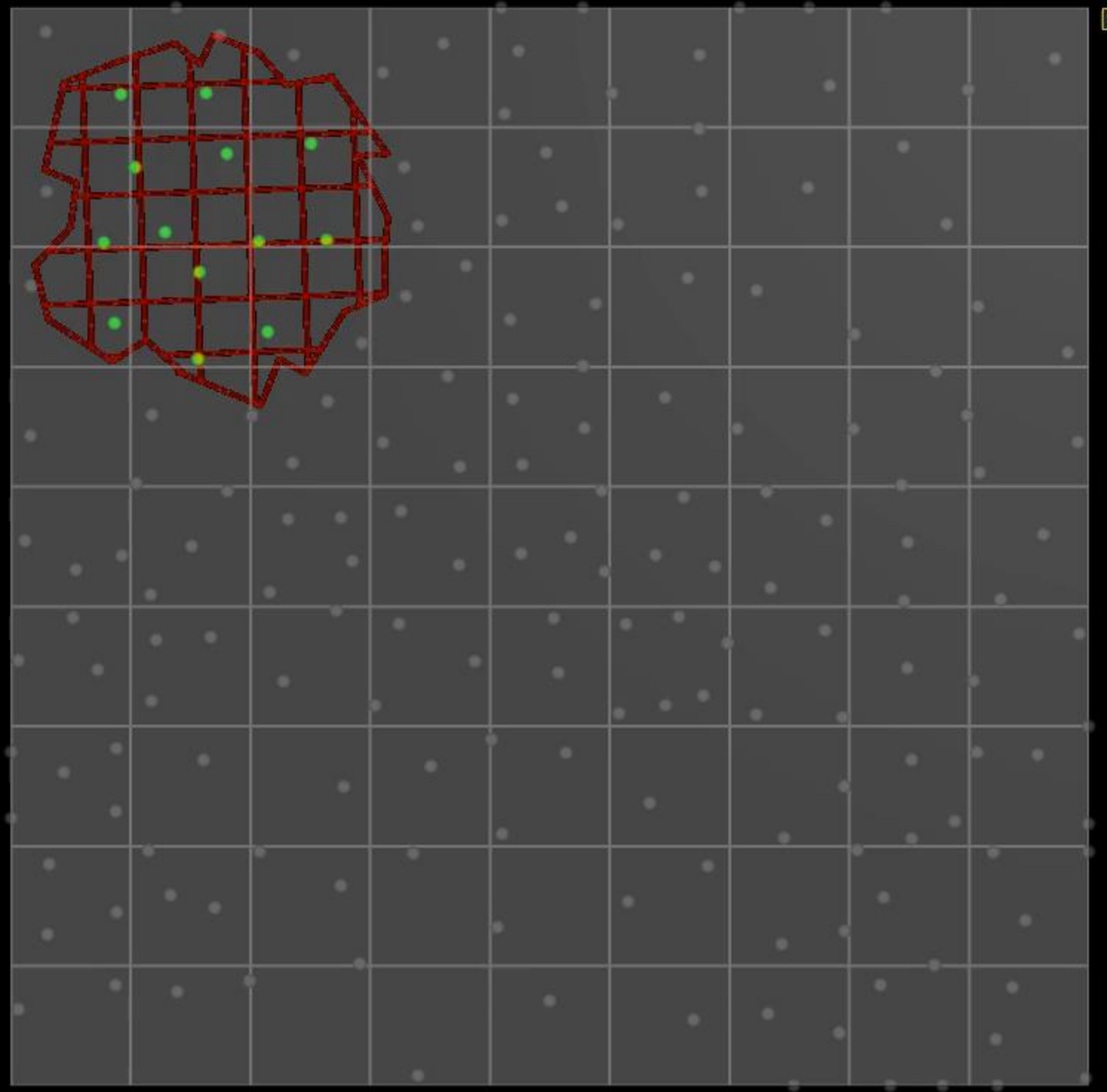
1. Calculate hi-res narrow-band SDF of input
2. Convert SDF to fog volume to activate interior
3. Copy active voxels to half-res, axis-aligned background VDB
4. Dilate active voxels by jitter scale
5. Run multithreaded VEX over active voxels to generate jittered points inside SDF



SIDE EFFECTS SOFTWARE

Sparse Points From Volume
Half-res Background VDB

- Gives constant “jitter space”
  - Sand emission
  - Tricky to create, easy to remove
- Control over multithreading
  - Hi-res slow at ~1 point per voxel
  - Better ~8 or even ~64
-
```
for(i=0; i < ptspervox; i++)
{
 pos = @P + getjitter(@P, i);
 if(volumesample(pos) < 0)
   addpoint(pos);
}
```

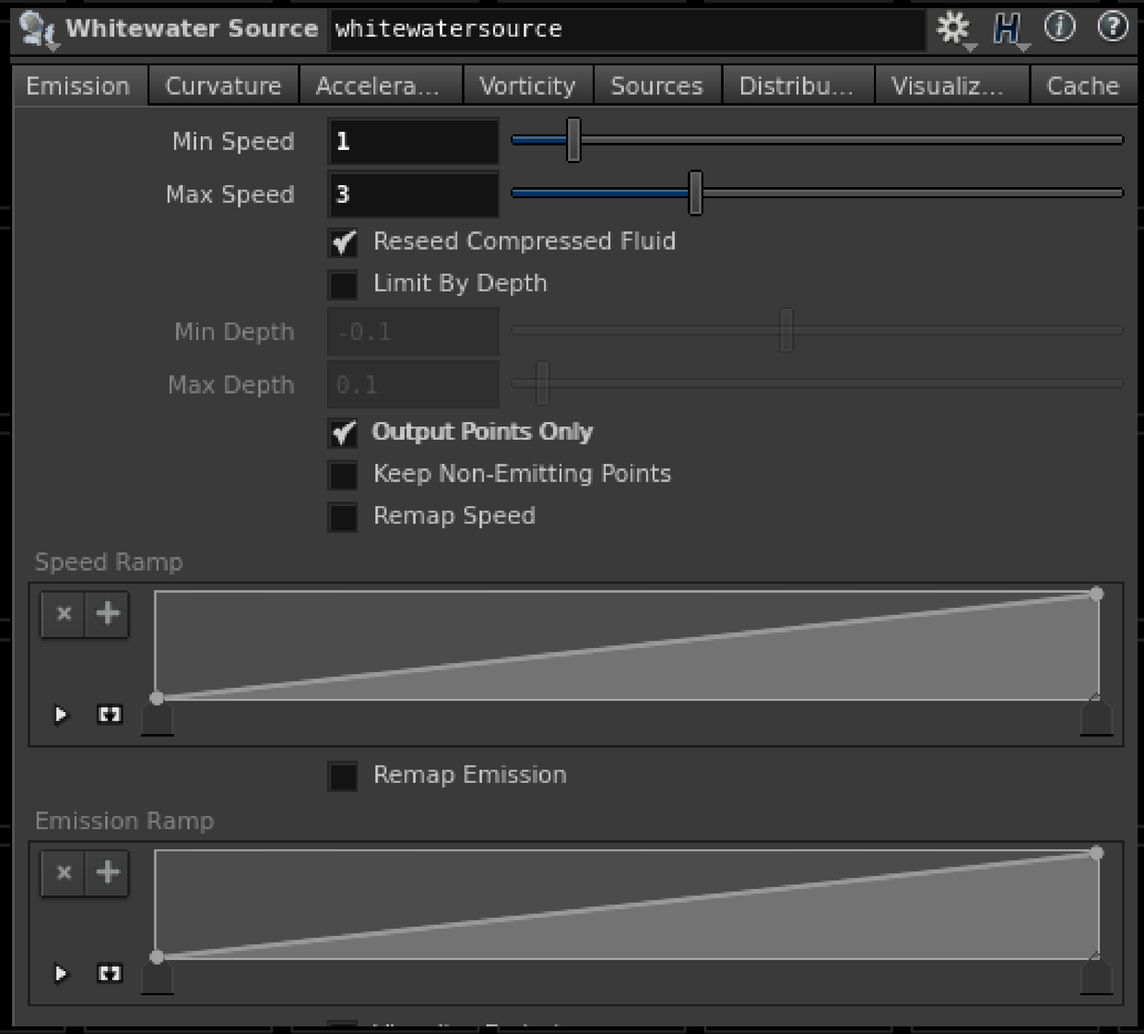


SIDE EFFECTS SOFTWARE

Sparse Points From Volume Whitewater Emission

1. FLIP particles as input
2. Hard cull on depth and velocity
3. Sample acceleration, vorticity, curvature from simulation fields
4. Map to emission probability
5. Cull zero emission

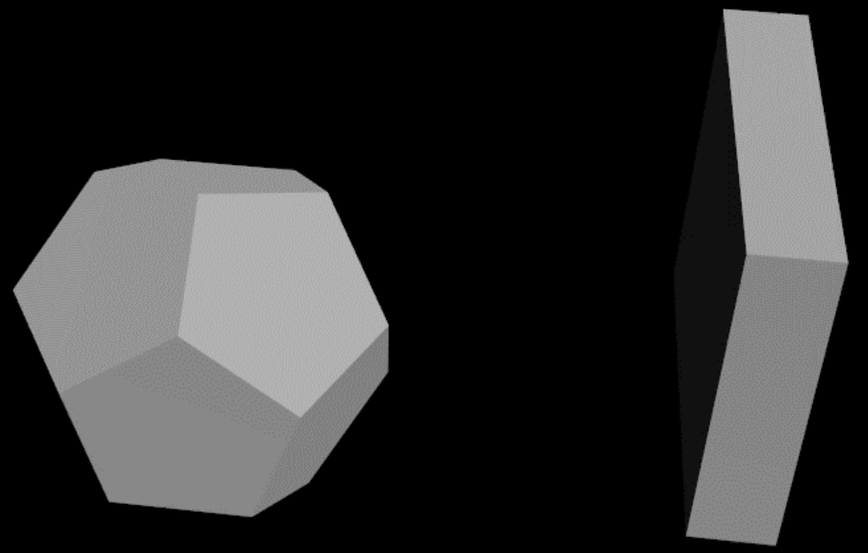
Reseeding needs to feed into step 3!



SIDE EFFECTS SOFTWARE

Sparse Points From Volume Whitewater Active Area

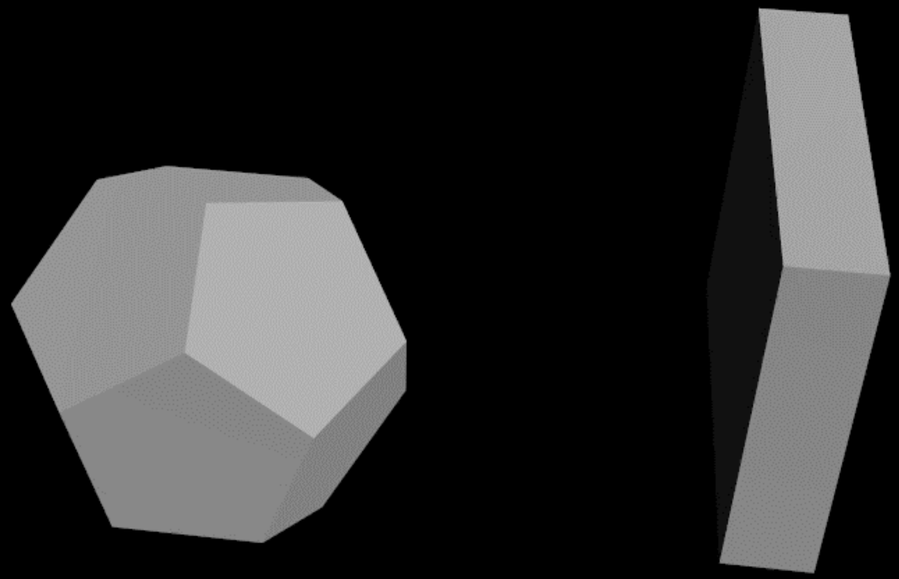
- Map velocity to 0-1 fog
  (VDB Analysis)
- Map culling depth and depth limit to 0-1 and combine with velocity
  (VDB Combine)
- De-activate zero regions
  (VDB Activate)



SIDE EFFECTS SOFTWARE

Sparse Points From Volume Reseeding Active Area

- Generate points in active voxels (PointsFromVolume)
- Sample velocity field (AttribFromVolume)
- Feed into Whitewater emission criteria



SIDE EFFECTS SOFTWARE

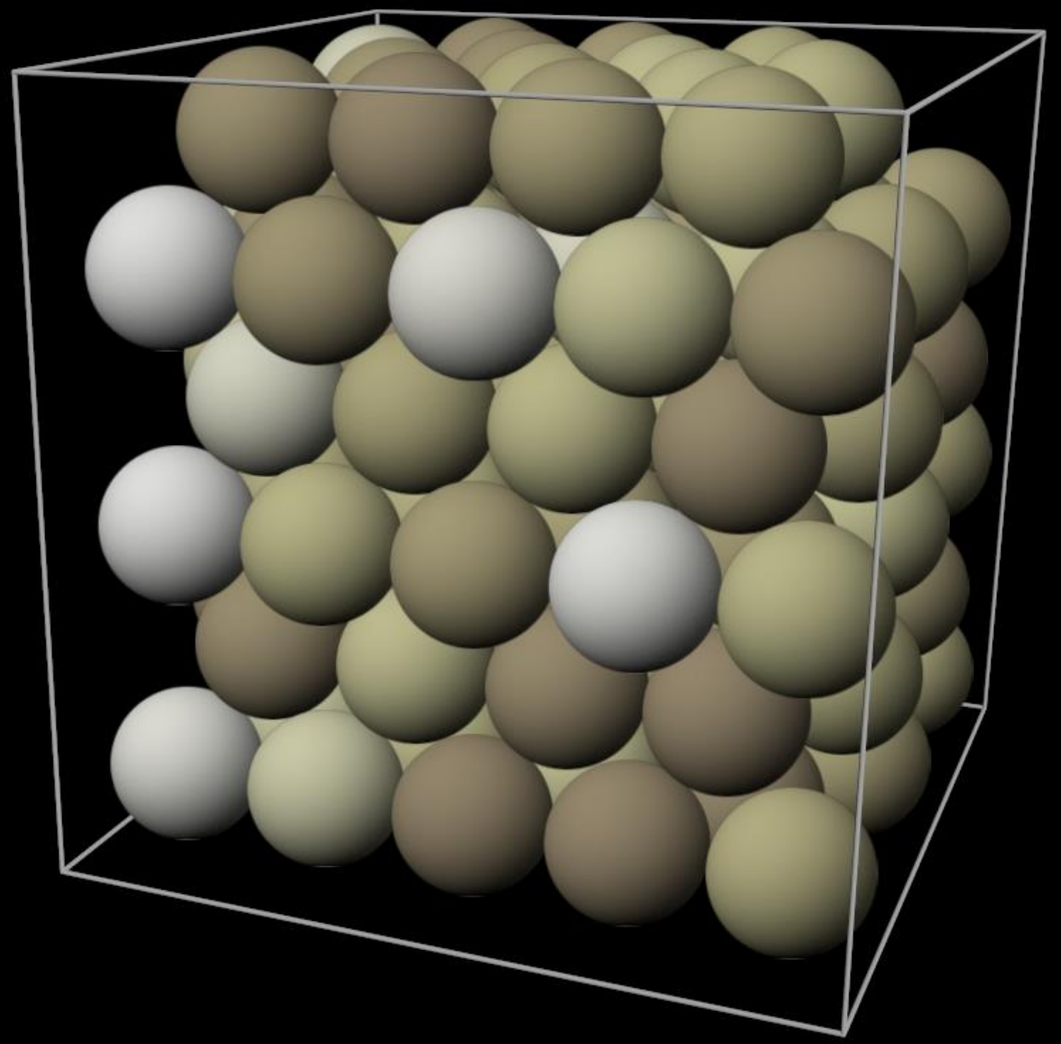
Sparse Points From Volume
Sparse Example

- 80M particle adaptively distributed FLIP sim
- 10M particles compressed
- Spliced with VDB ops
- VEX-based high-order advection directly from VDB
- Pockets of whitewater
- Aeration important for look

SIDE EFFECTS SOFTWARE

Sparse Points From Volume
Why Not VDB Scatter?

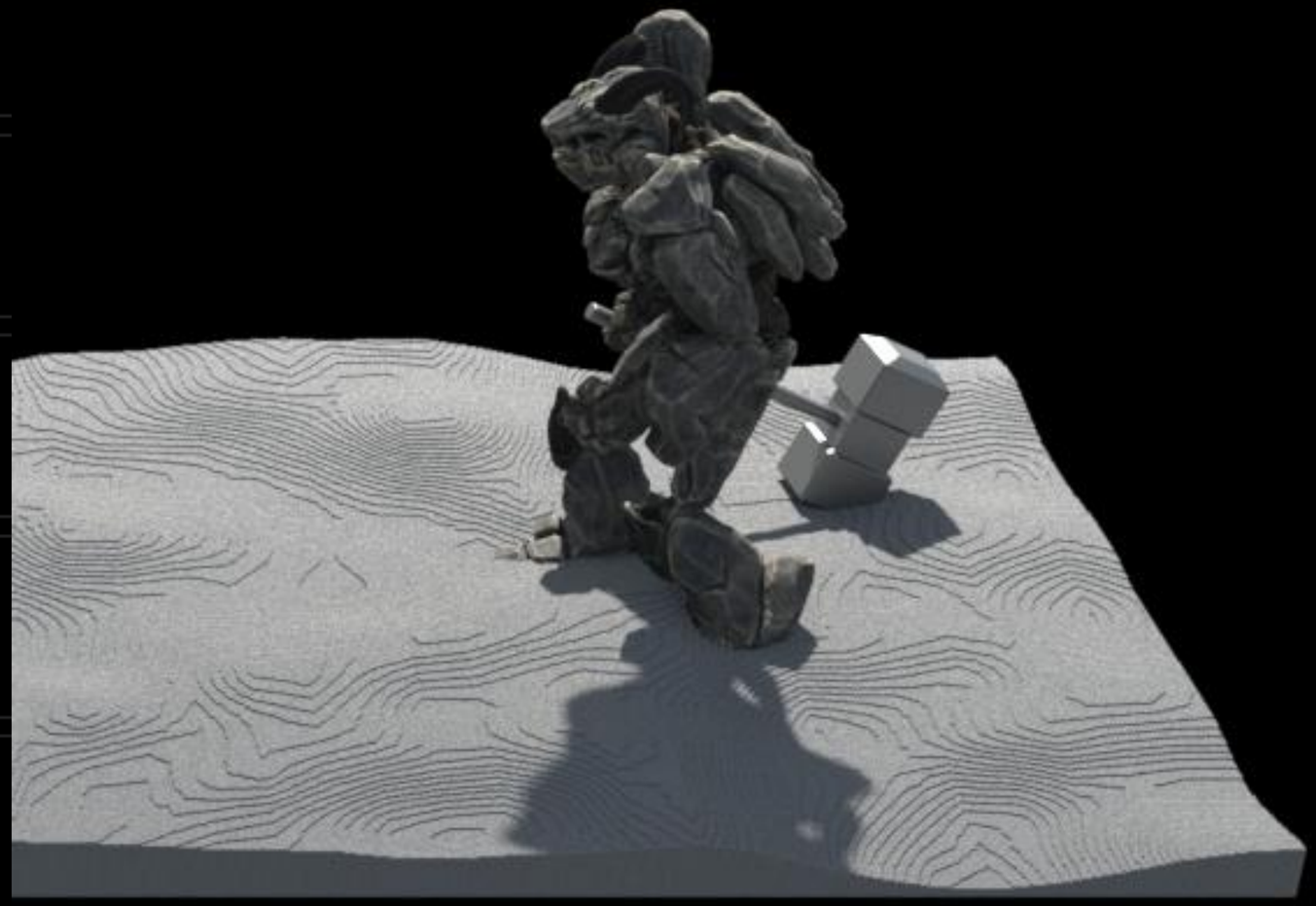
- Does not use standard VDB C++ scatter operator
- Specific point configurations
  - Boundary oversampling
  - Tetrahedral packing
- Purely constructive avoids data structure fragmentation



SIDE EFFECTS SOFTWARE

Sparse Points From Volume Grain Generation

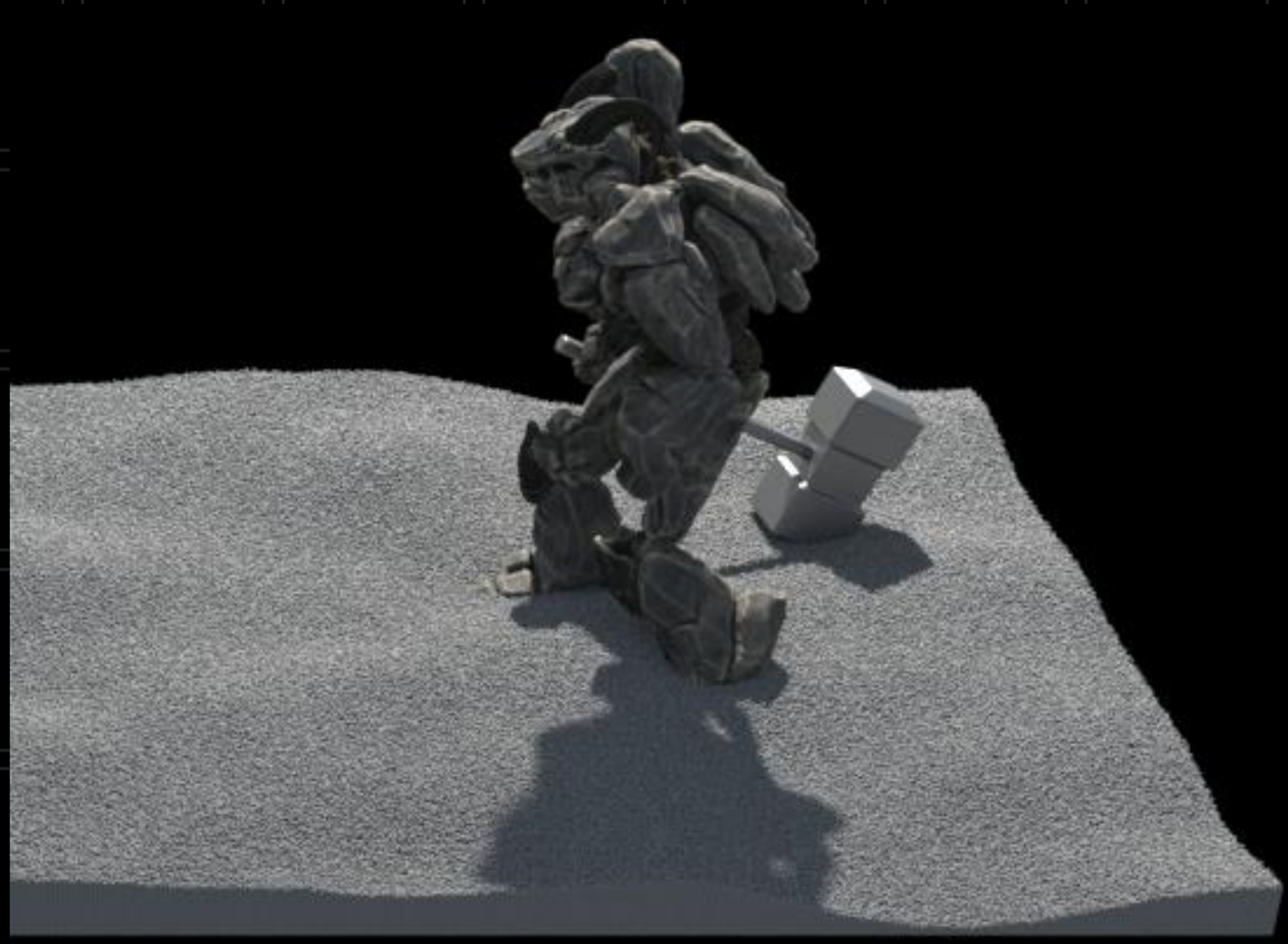
- Sandbox tool creates grains from extruded volume
- Structured points with strict SDF rejection produces ridge artifacts



SIDE EFFECTS SOFTWARE

Sparse Points From Volume Dithering

- Dither!
- Update VEX code to make SDF test probabilistic close to isosurface
- Removes artifact but retains low-energy configuration



SIDE EFFECTS SOFTWARE

VDB-based Particle Activation

- Activation from nearby fast-moving neighbors (pgfind)
- Activation from dilated collision VDB (VDB Reshape SDF)
- Activation by castle volume (VDB From Polygons)
- Natural-looking activation from low-energy point configuration

SIDE EFFECTS SOFTWARE

Surfacing

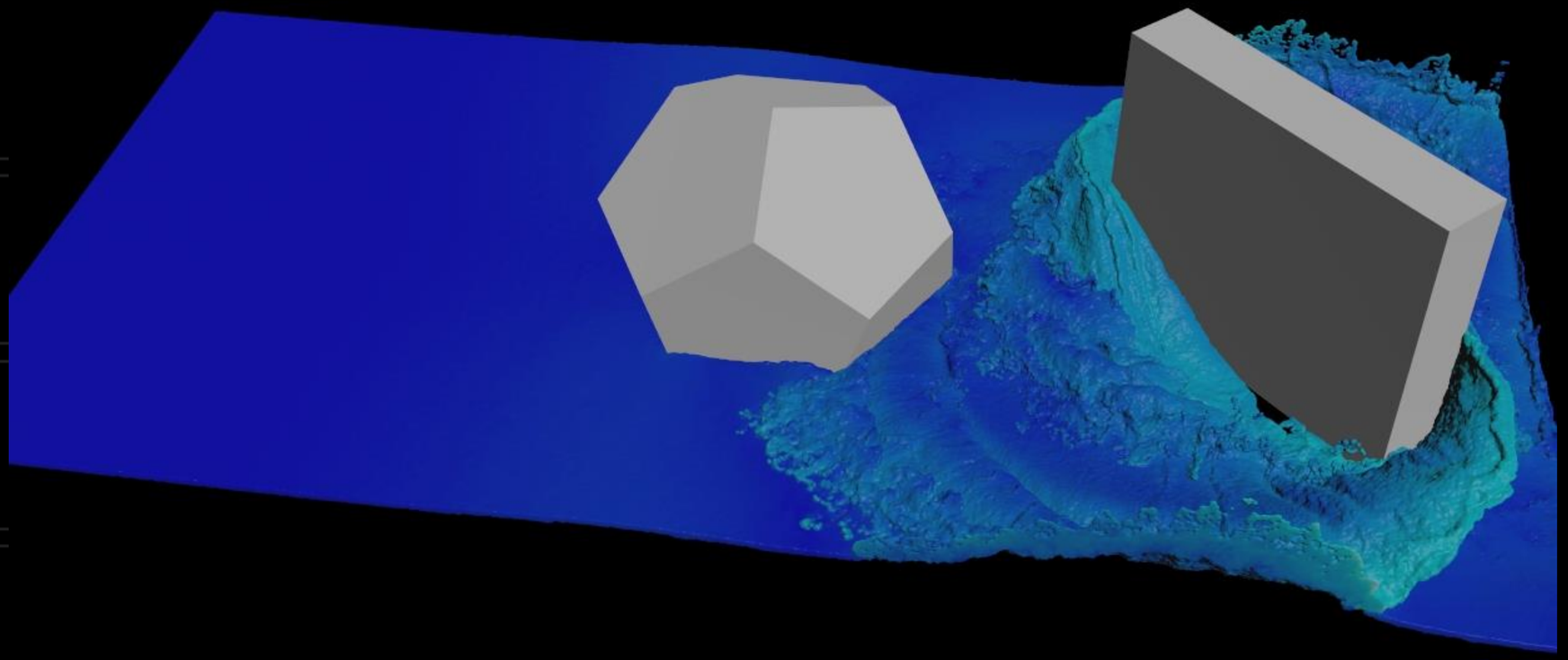
- Create high-quality polygonal mesh from compressed fluid input
- Provide filtering and morphological operations
- Generate spatially varying masks to allow control over filtering
- Output adaptive polygon mesh
- “Liquid in the Croods”
  - Budsberg et al.

Surfacing
Initial Surface

- Create narrow-band SDF from particles

- VDB From Particle Fluid (H13)
  - Average Position
  - Ghost points
  - Less post-processing
  - Less control

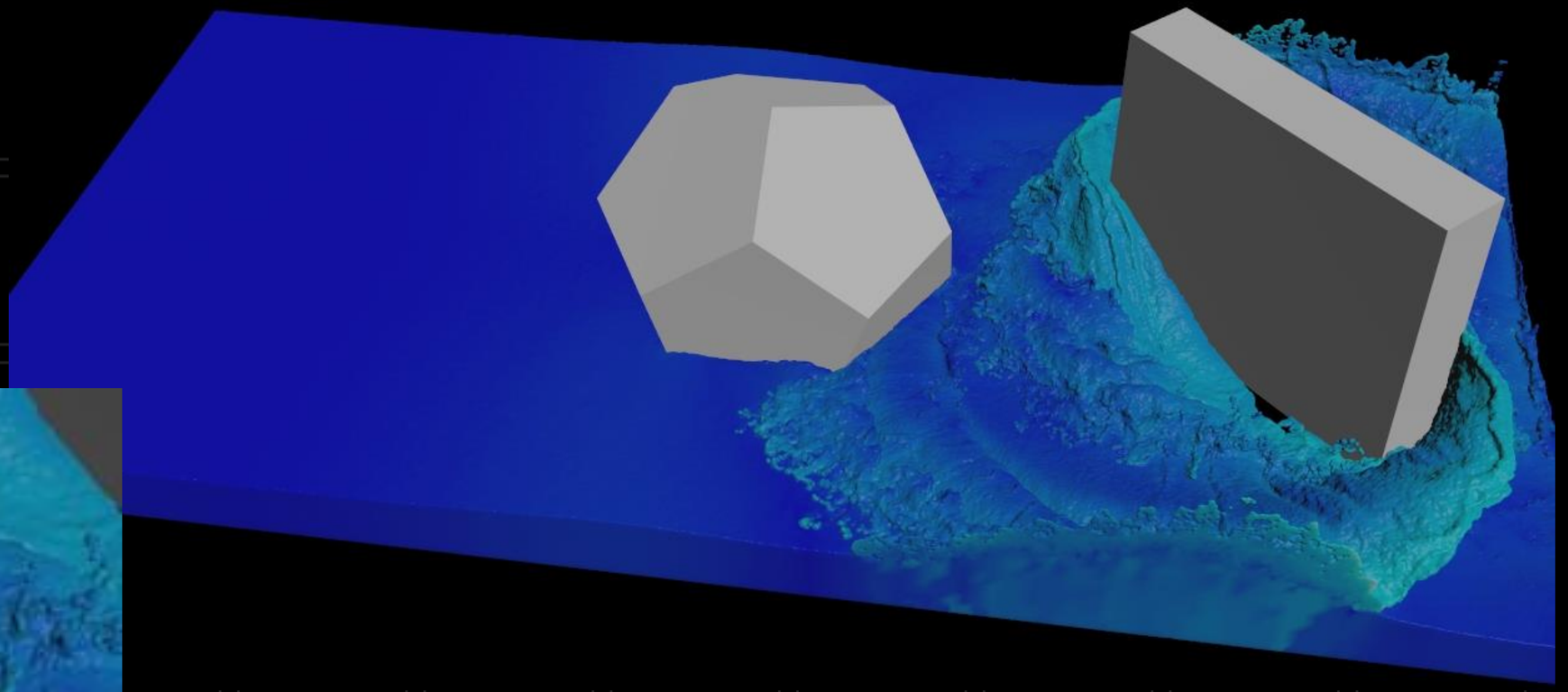
- VDB From Particles
  - Spherical
  - Scales very well
  - Requires post-processing
  - More control



SIDE EFFECTS SOFTWARE

Surfacing
Union

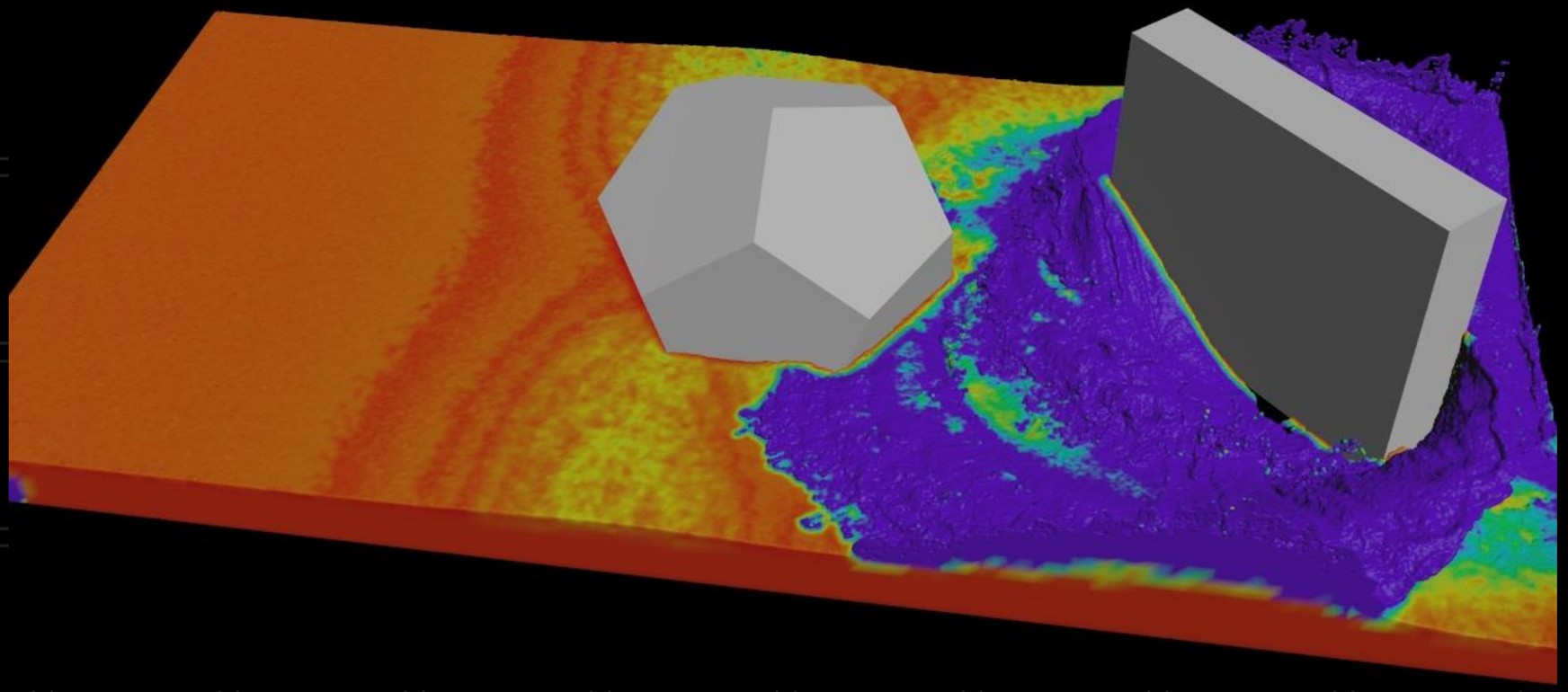
- Erode surface SDF by particle compression bandwidth
  - VDB Reshape SDF
- Union with particle surface
  - VDB Combine
- Needs post-processing!



SIDE EFFECTS SOFTWARE

Surfacing
Spatially Varying Mask

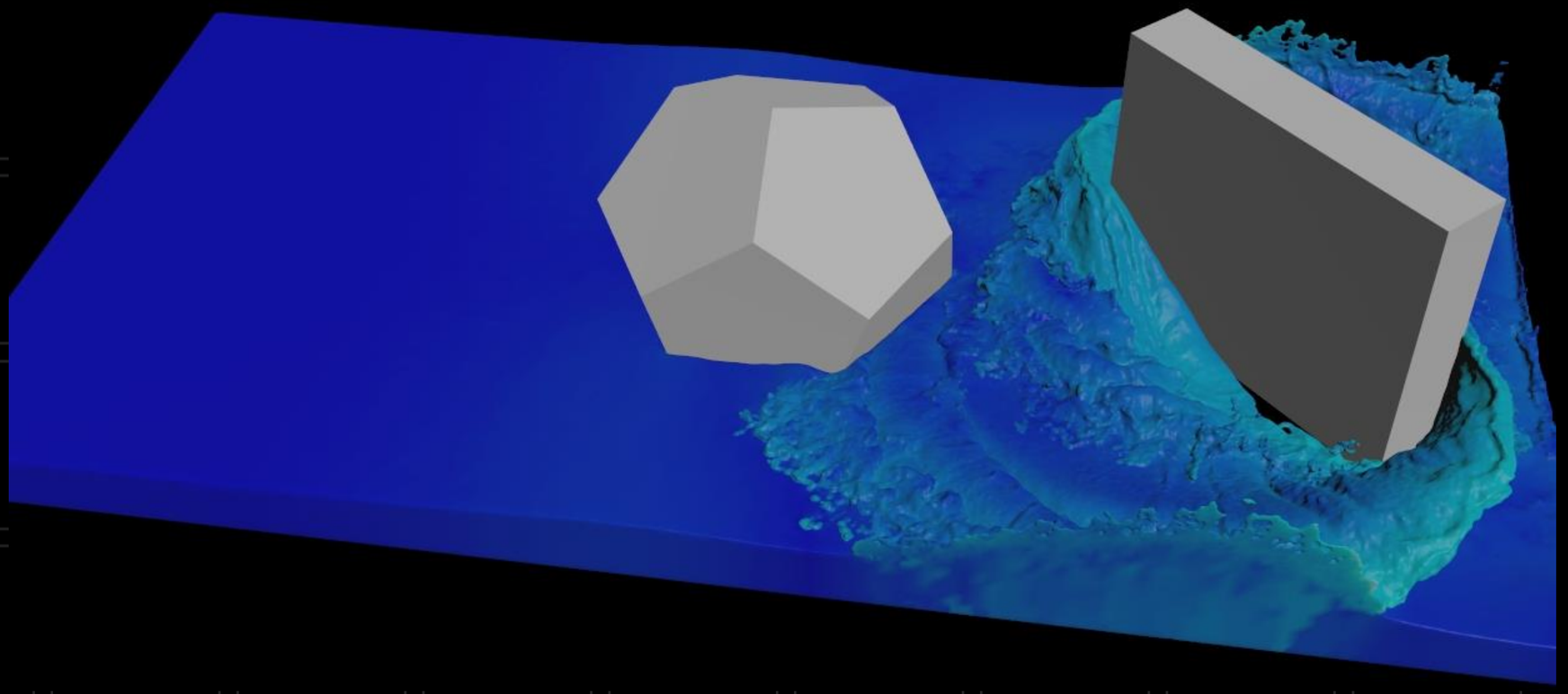
- Generate fog volume mask
  - Velocity
  - Vorticity
  - Collision proximity
  - User provided VDB
    - VDB Analysis
    - VDB Combine
- Use to modulate filtering



SIDE EFFECTS SOFTWARE

Surfacing
Morphological Ops and Filtering

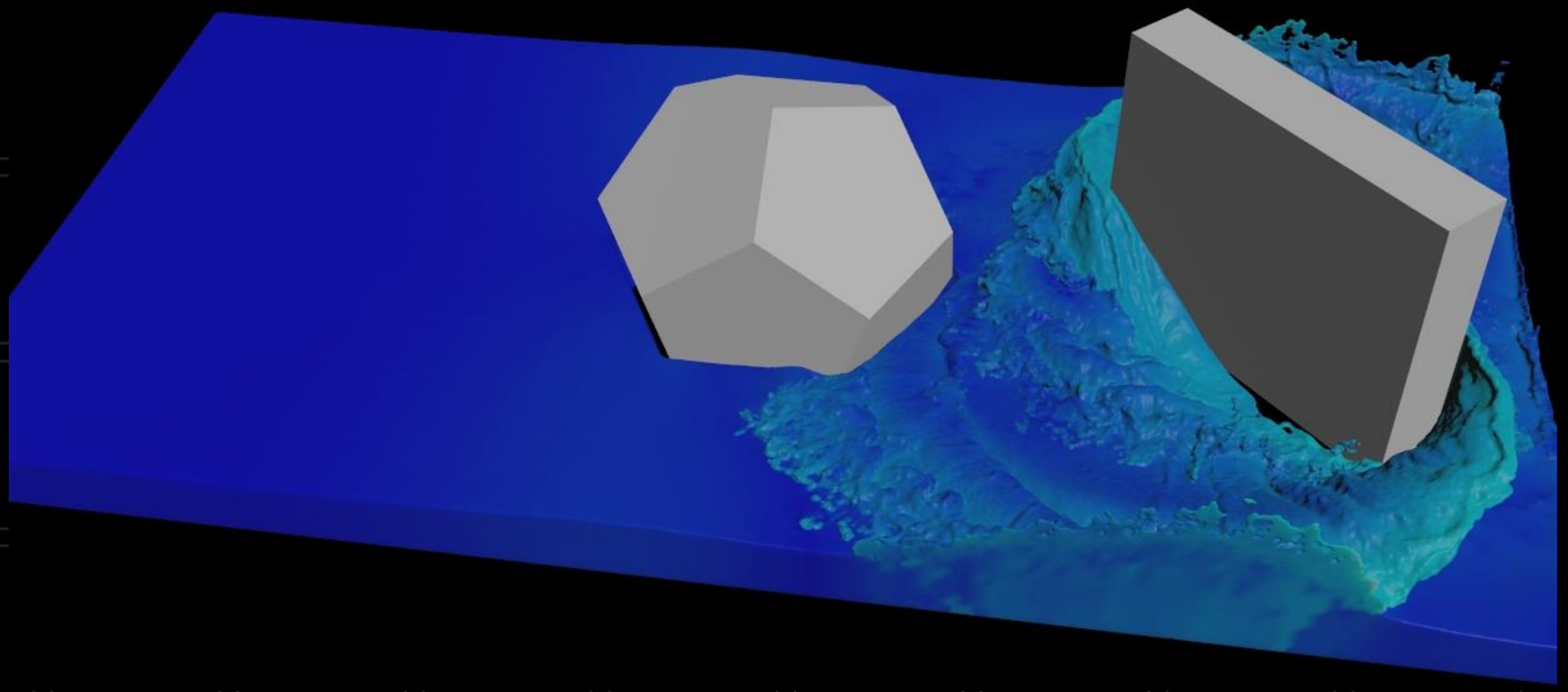
- Dilate / Smooth / Erode
  - “Close” operation
  - 2nd order smoothing
- Stronger Final Smooth
  - Gaussian
  - Usually masked



SIDE EFFECTS SOFTWARE

Surfacing
SDF Operations

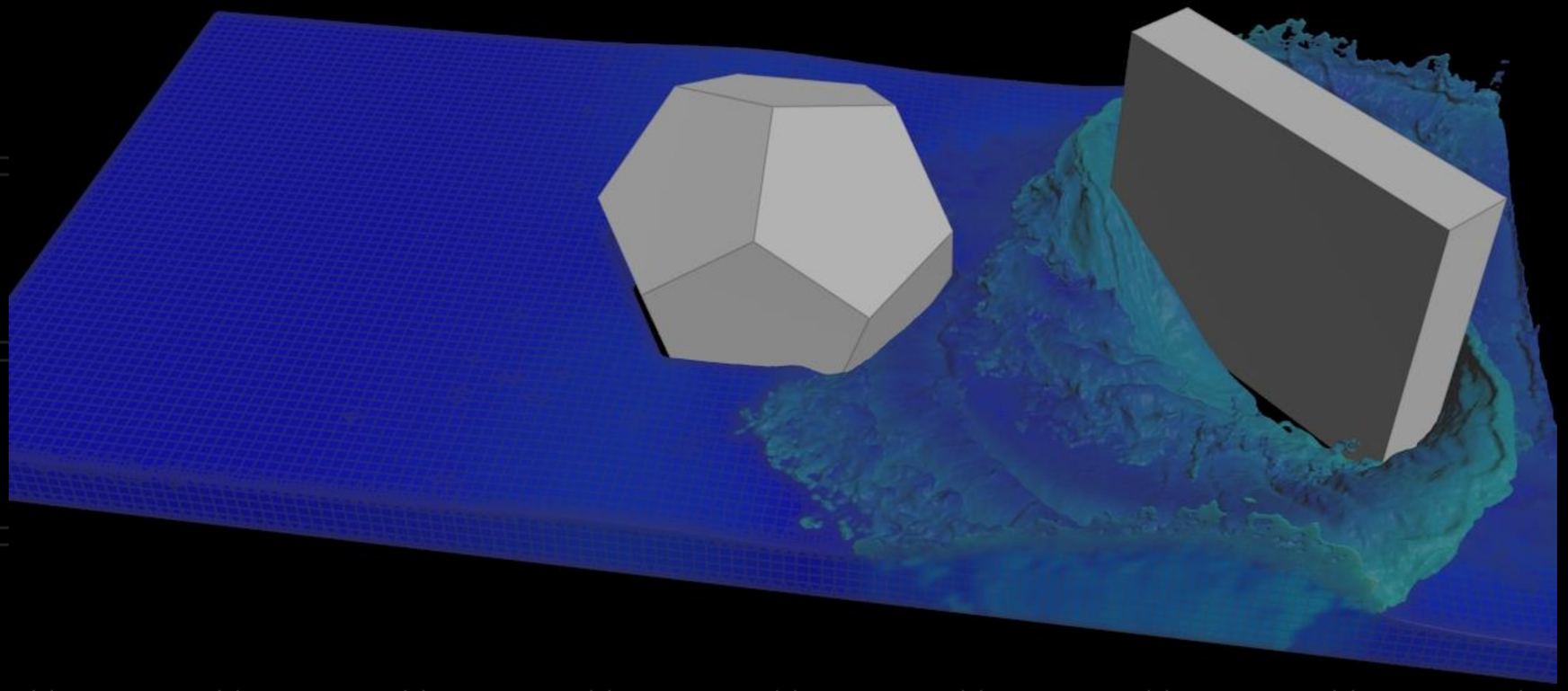
- Subtract Collisions
  - VDB Combine
- Flatten edges at boundary
  - VDB Combine
  - VDB Morph



SIDE EFFECTS SOFTWARE

Surfacing
Adaptive Polygonal Mesh

- Fewer polygons at low curvature
- Reduced memory and rendering requirements
- Additional level of smoothing



SIDE EFFECTS SOFTWARE

Surfacing
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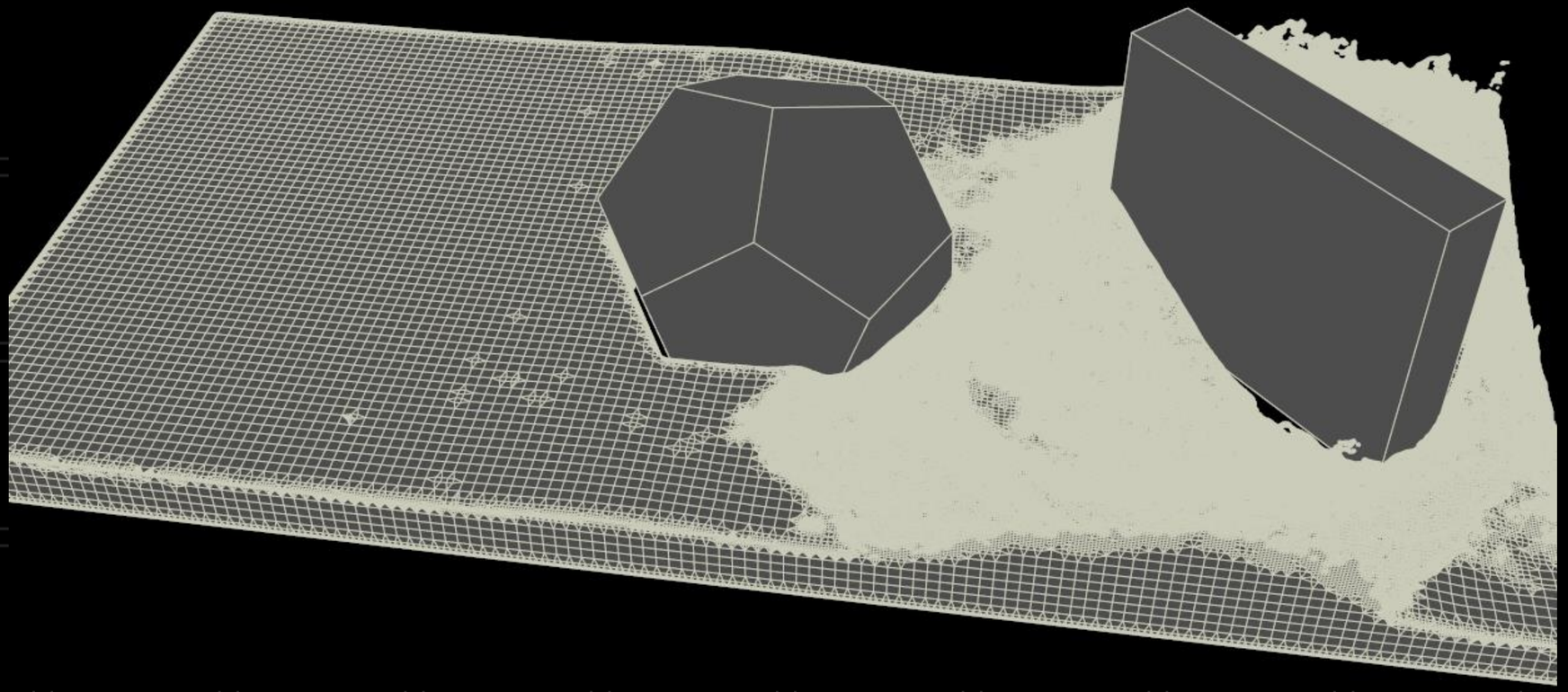
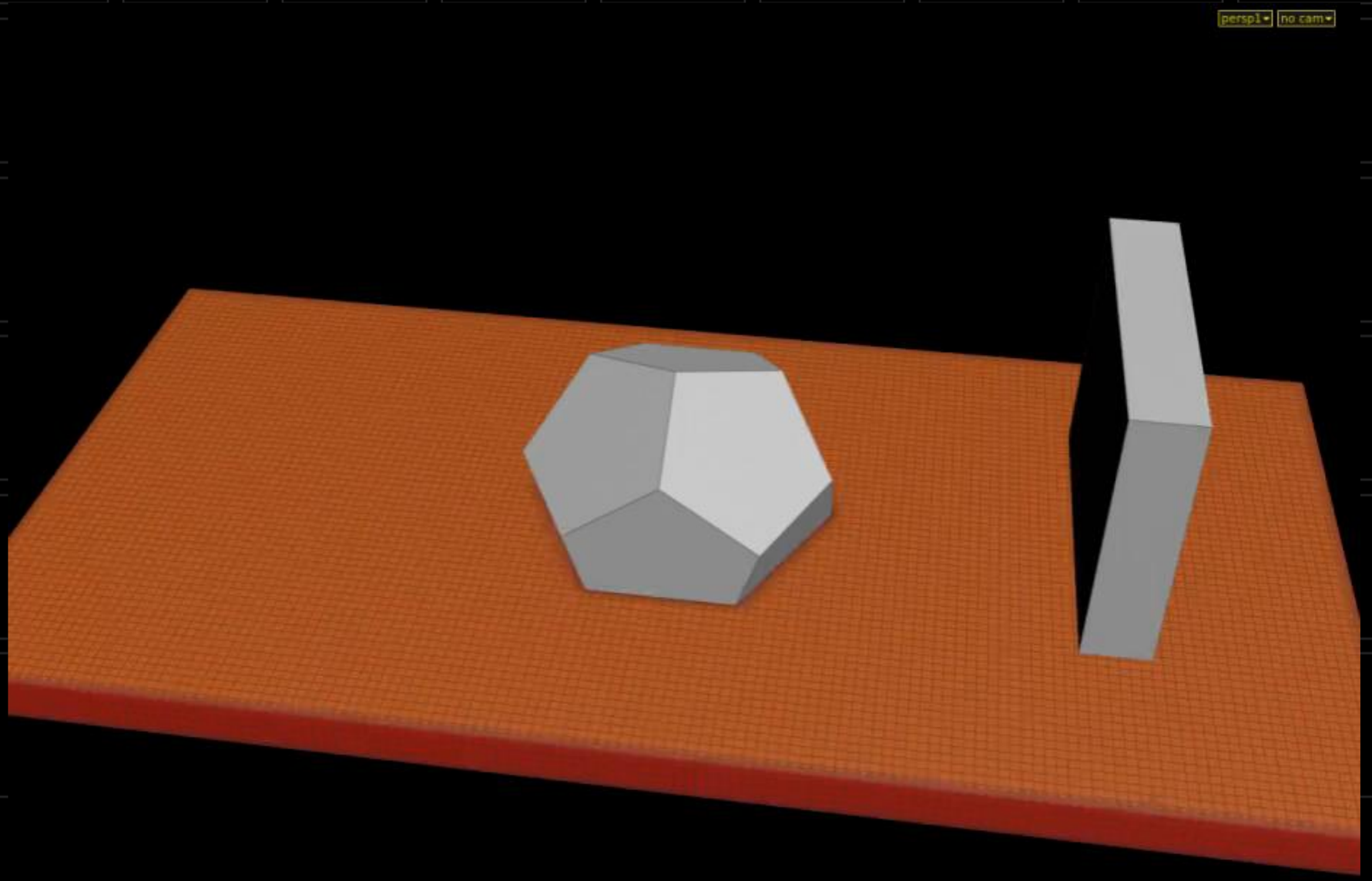


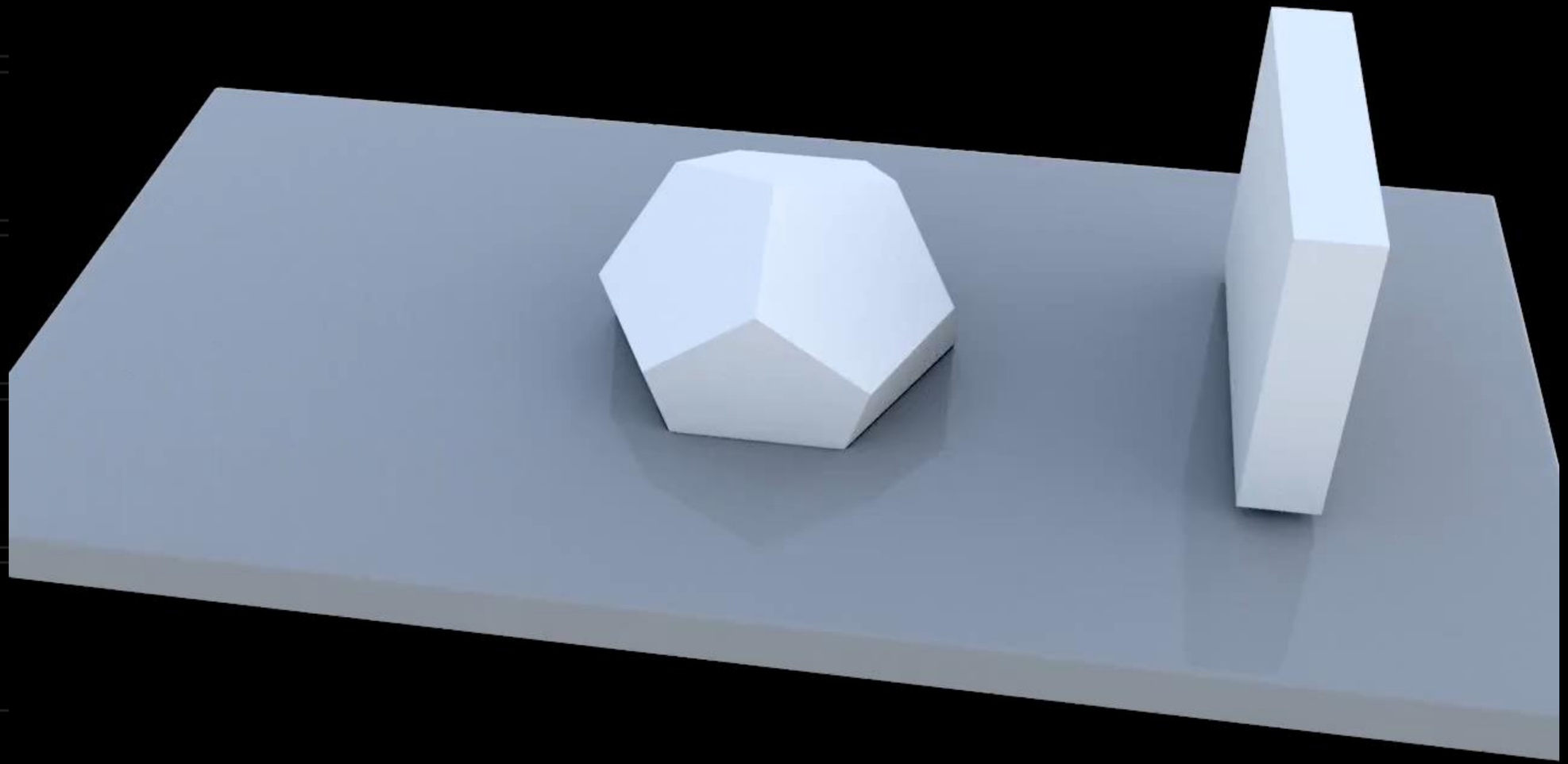
SIDE EFFECTS SOFTWARE

Surfacing Results



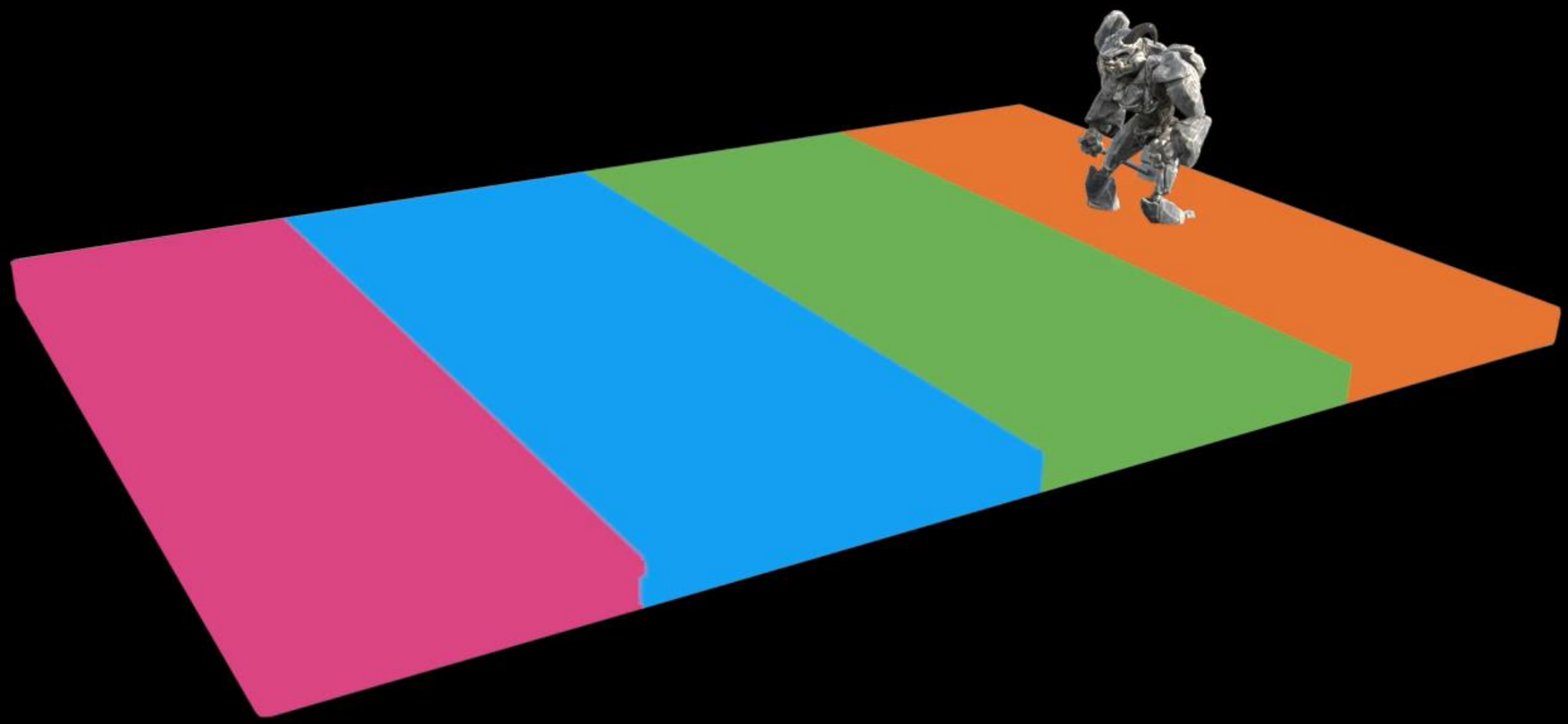
SIDE EFFECTS SOFTWARE

Surfacing Results



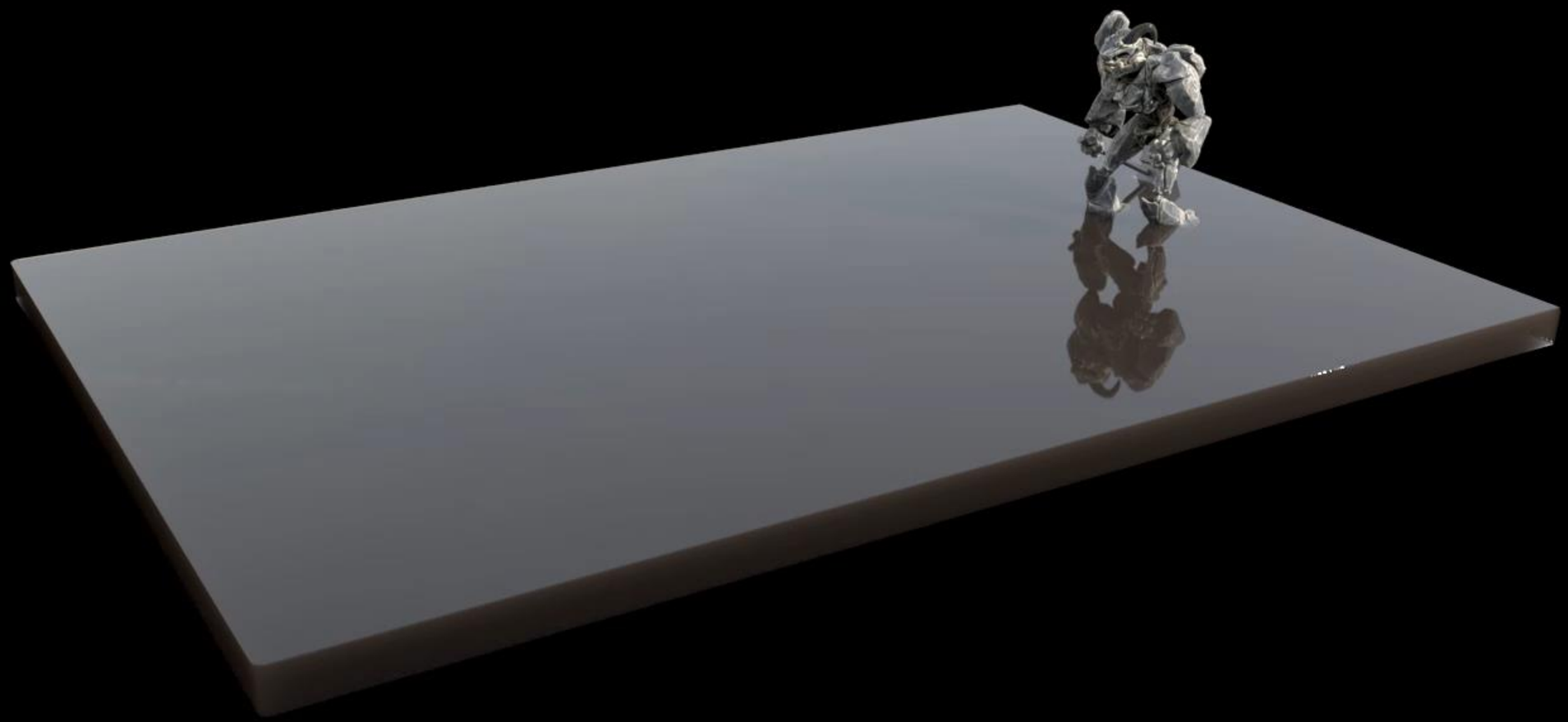
SIDE EFFECTS SOFTWARE

Surfacing Results



SIDE EFFECTS SOFTWARE

Surfacing Results



SIDE EFFECTS SOFTWARE

Thank you

SIDE EFFECTS SOFTWARE