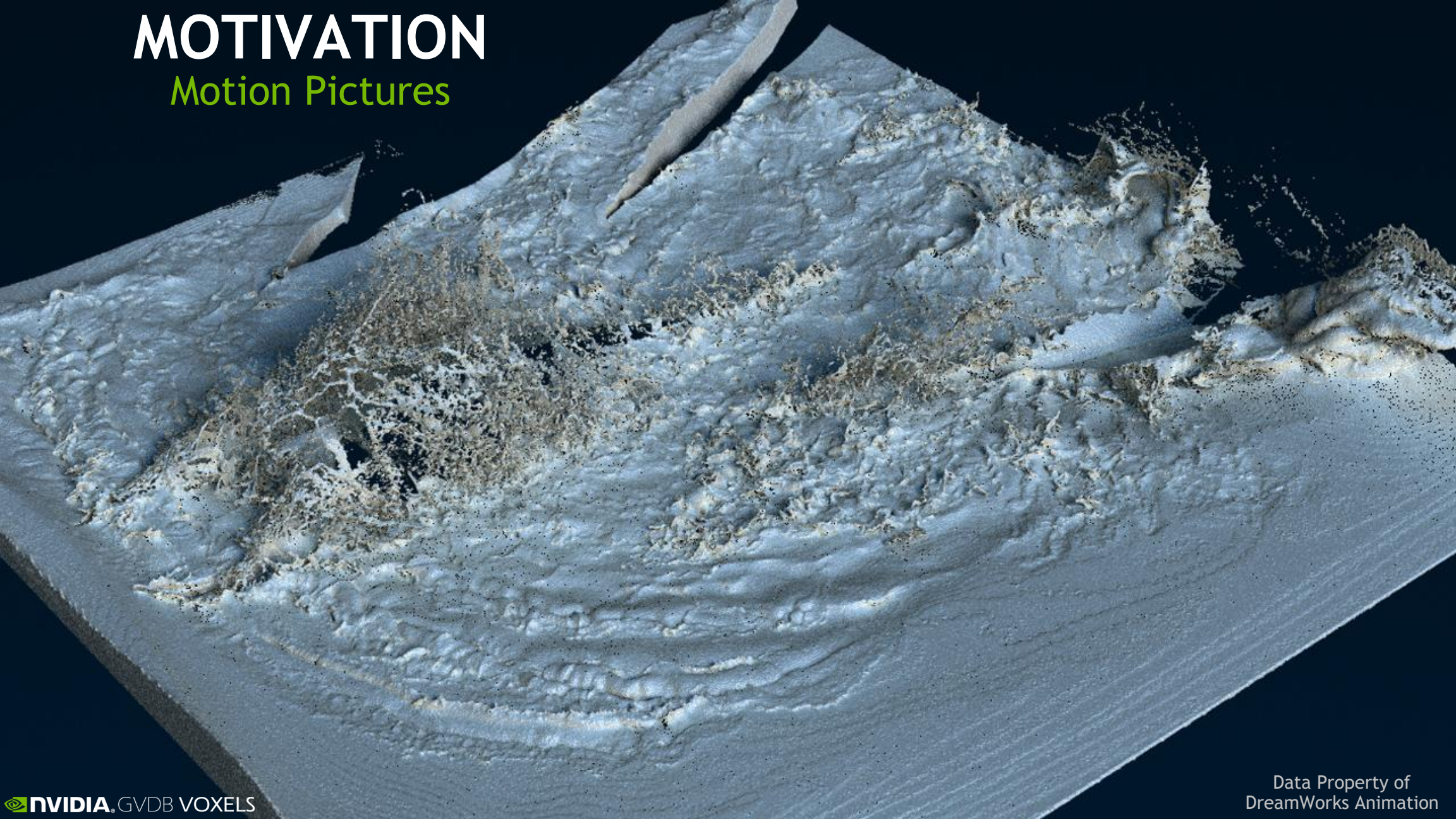
INTRODUCTION AND TECHNIQUES WITH NVIDIA® GVDB VOXELS

Dr. Rama Hoetzlein, Lead Architect for GVDB Voxels

MOTIVATION

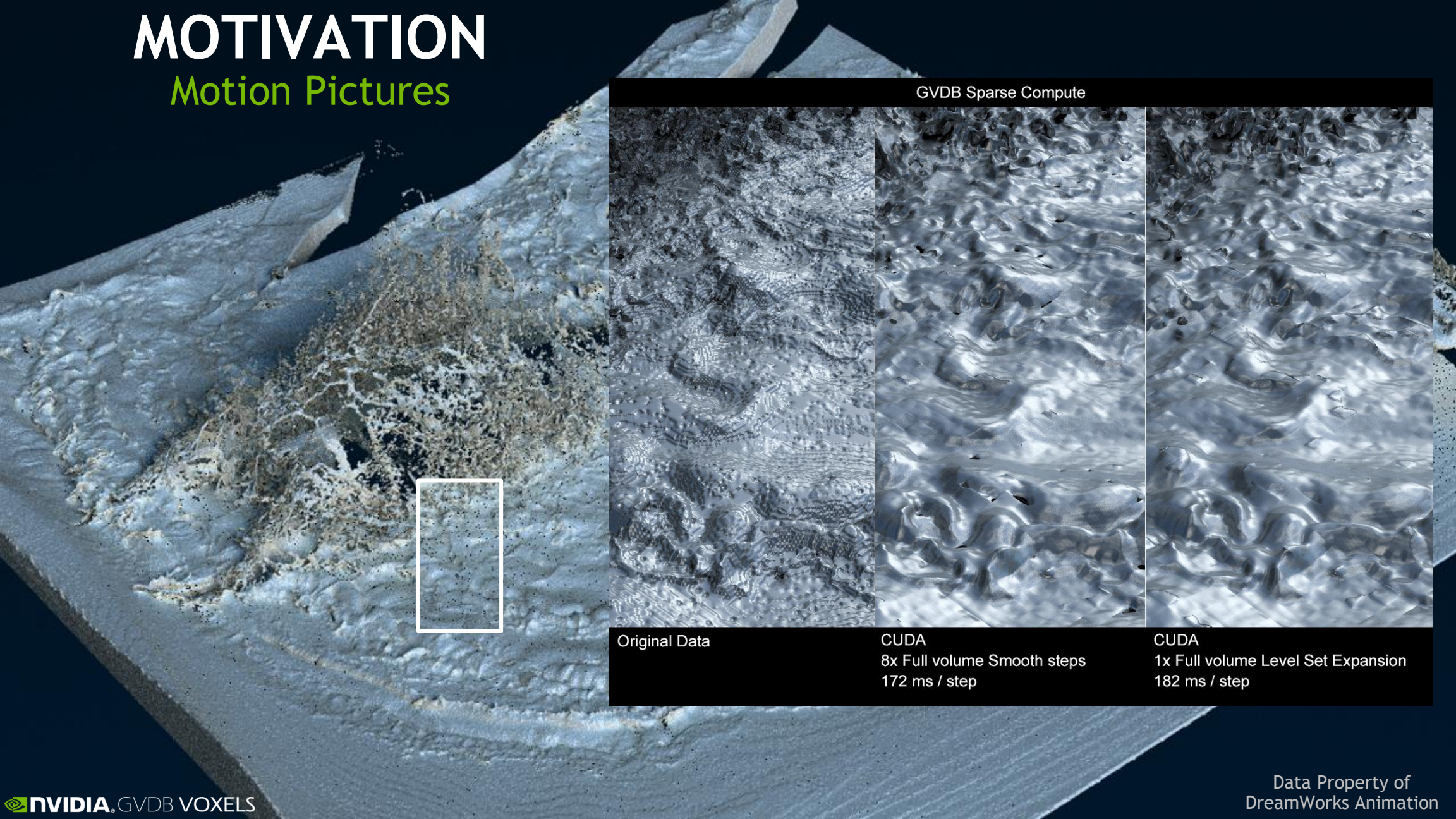
Motion Pictures



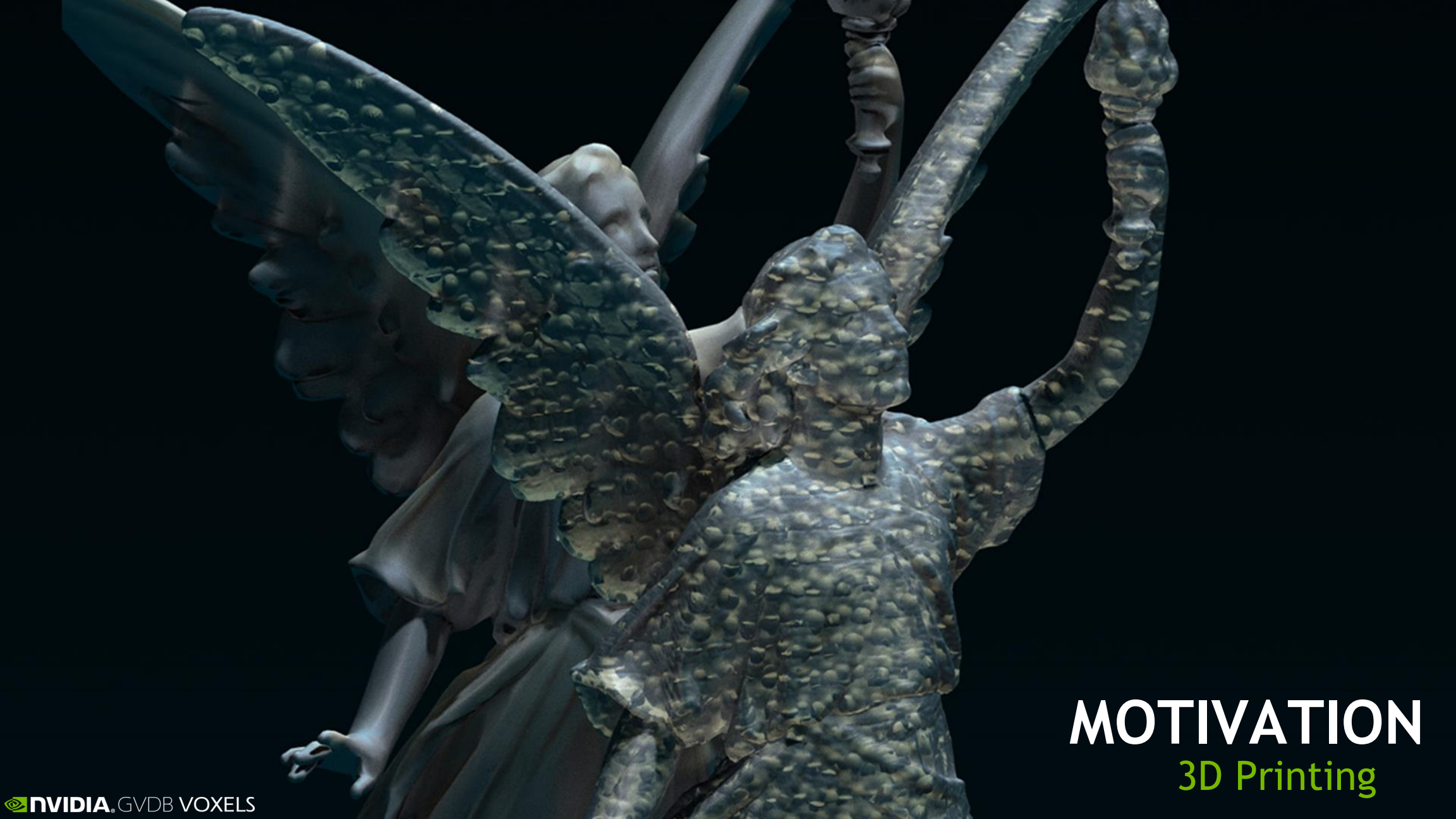
Data Property of
DreamWorks Animation

MOTIVATION

Motion Pictures

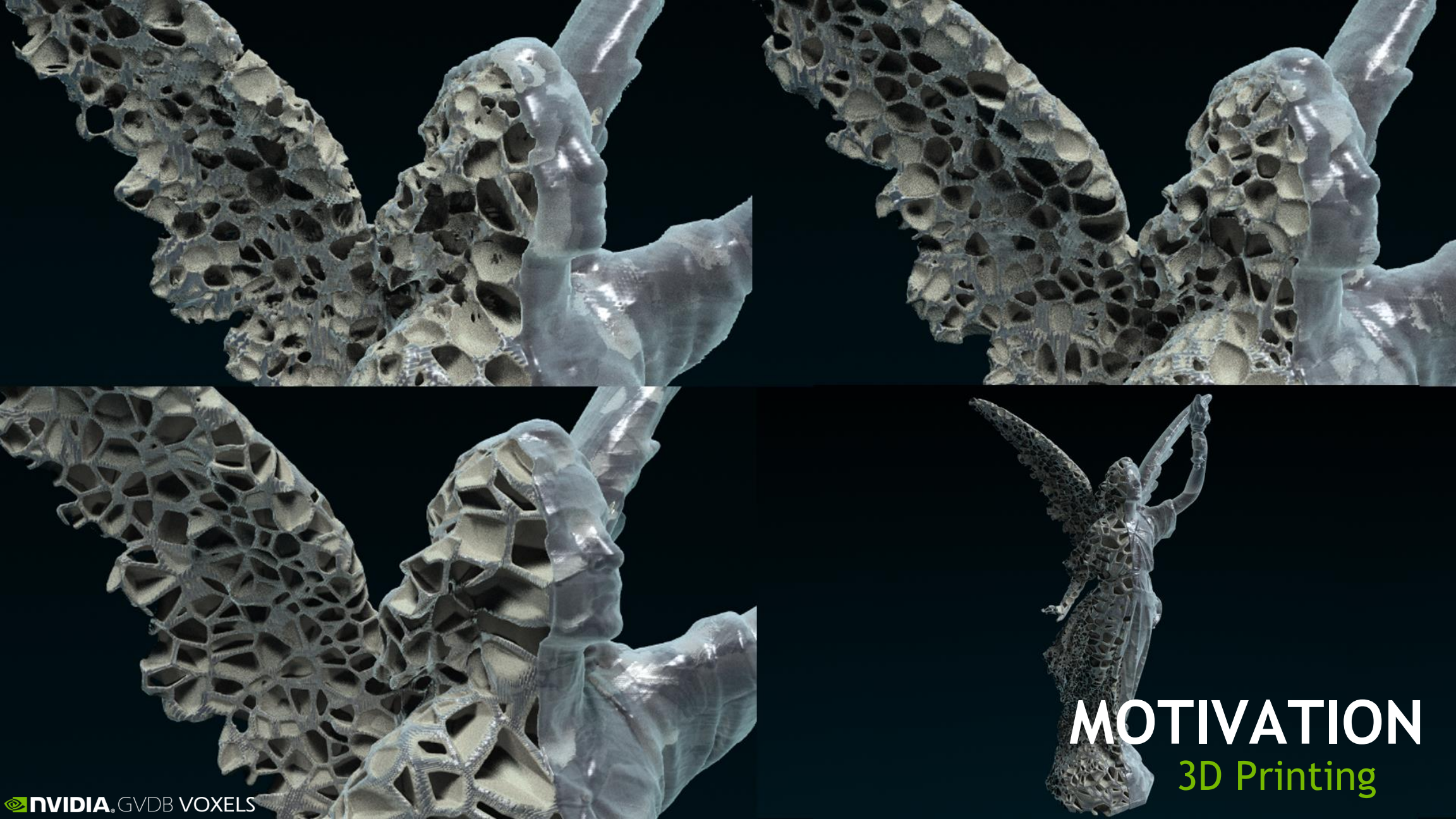


Data Property of
DreamWorks Animation



MOTIVATION

3D Printing

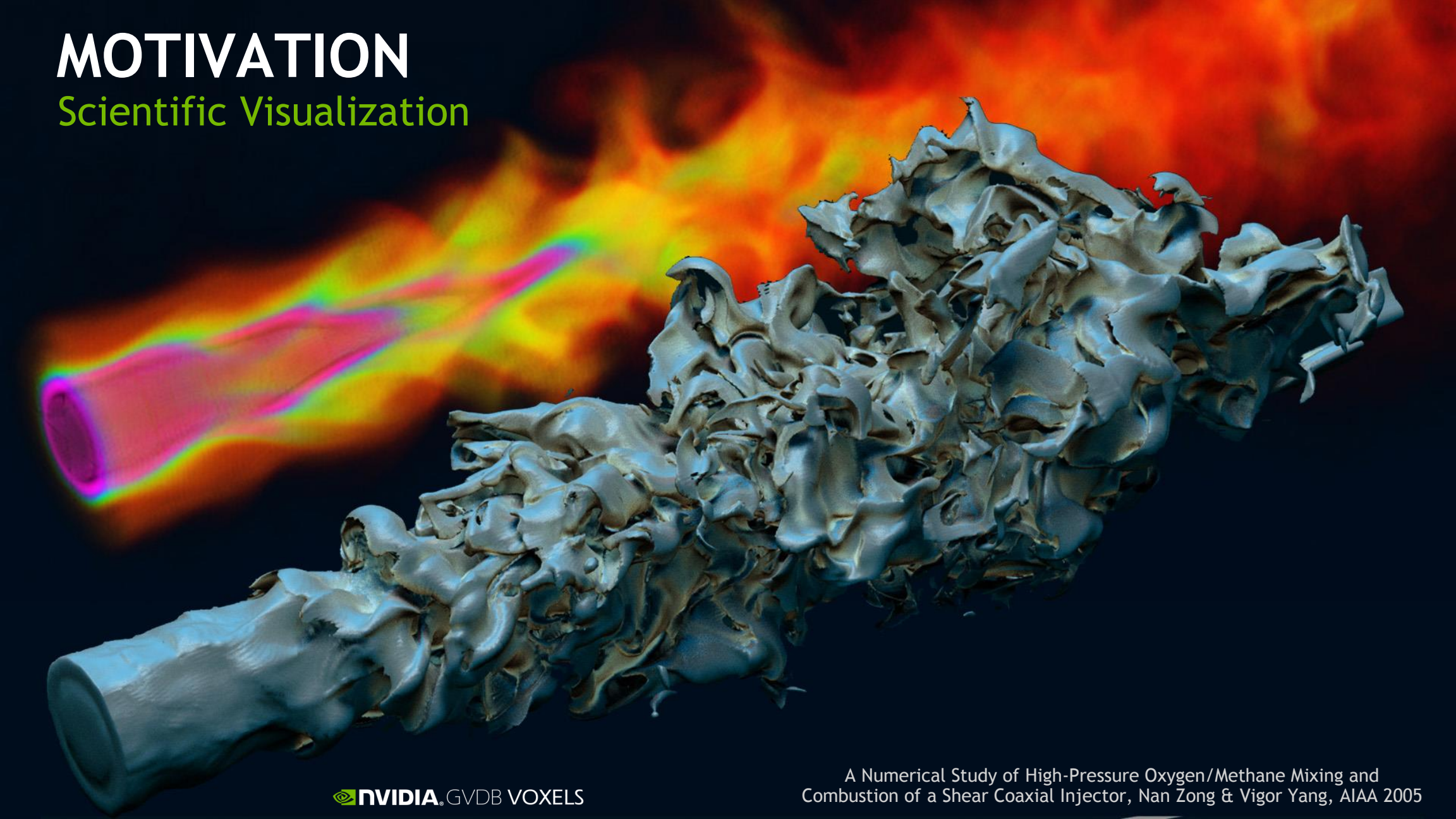


MOTIVATION

3D Printing

MOTIVATION

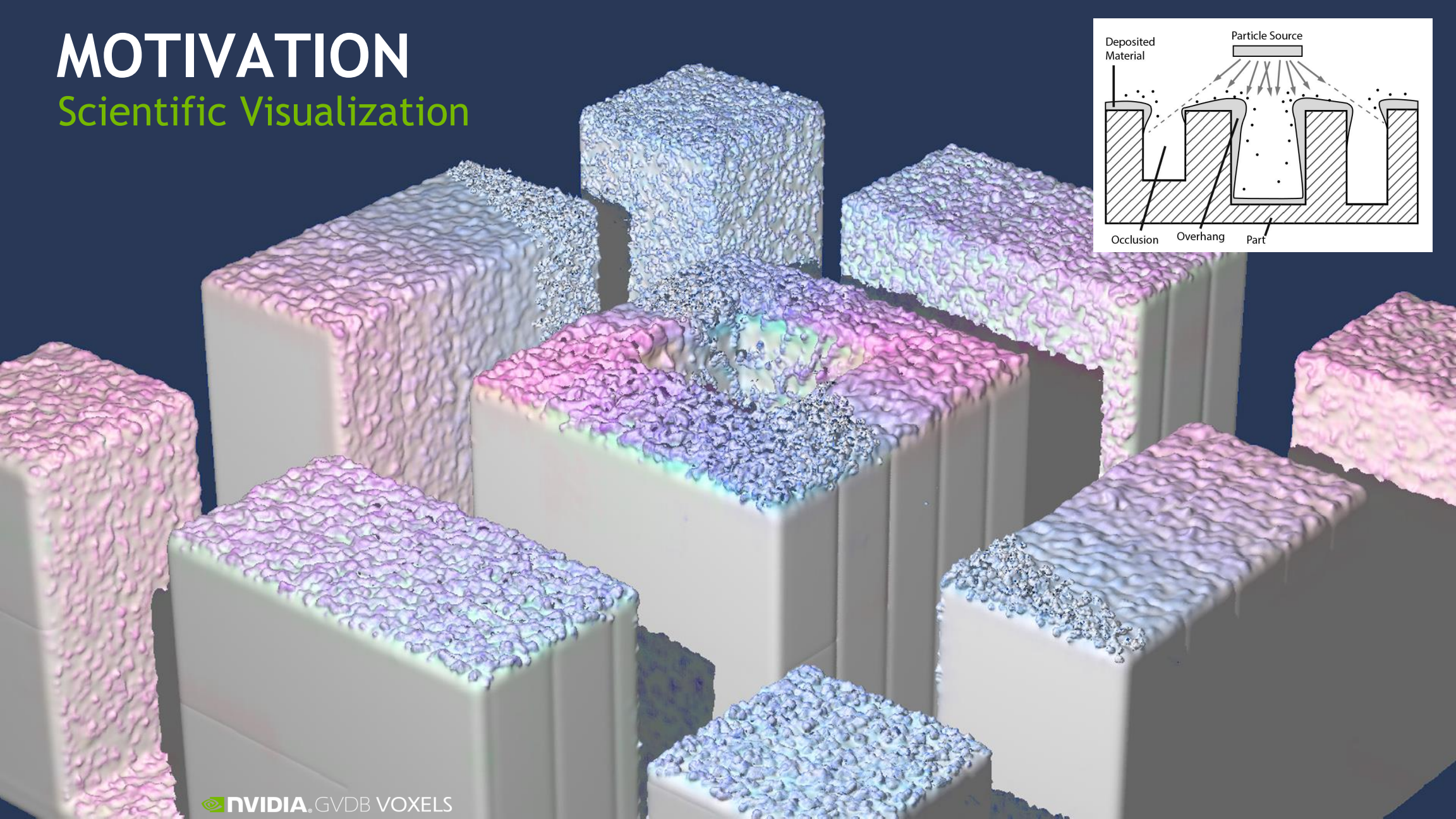
Scientific Visualization



A Numerical Study of High-Pressure Oxygen/Methane Mixing and Combustion of a Shear Coaxial Injector, Nan Zong & Vigor Yang, AIAA 2005

MOTIVATION

Scientific Visualization



INTRODUCING
NVIDIA® GVDB VOXELS

A new, open source NVIDIA SDK
for compute, simulation and rendering
of sparse volumes based on CUDA

OUTLINE

1. Overview
2. GVDB Features
3. Workflow
4. Compute API: Spray Deposition
5. Rendering API: OptiX Integration
6. Dynamic API: Fluid Surface

NVIDIA® GVDB VOXELS

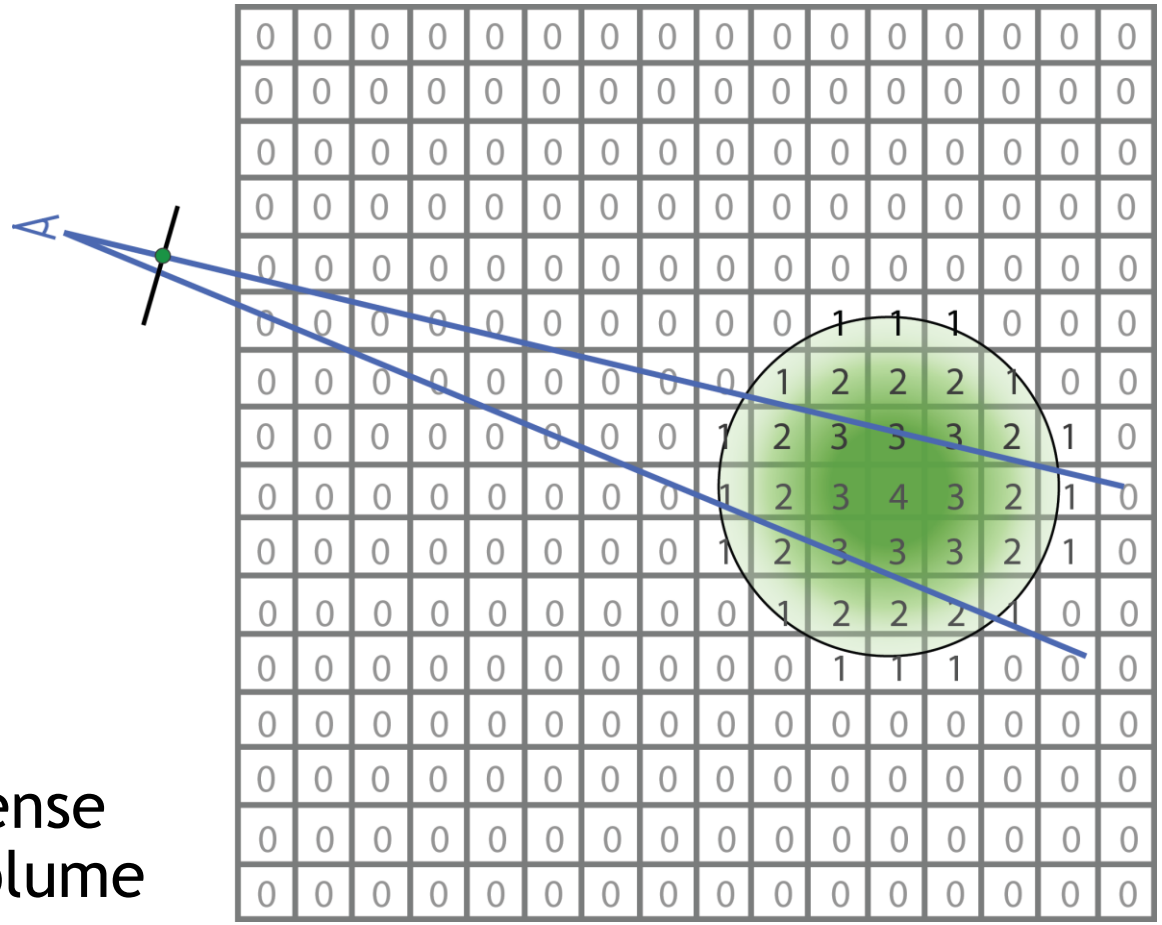
Overview

What is GVDB Voxels?

- An SDK library for **developers** to create applications in Motion Pictures, 3D Printing and Scientific Sim/Vis
- Abstracts the complexity of sparseness to support **compute** and **rendering** of high resolution volumes
- Based on **CUDA,** for portability to embedded devices (JetsonTX), Quadro/GeForce, Tegra/GRID
- Open source, fBor developers to customize

NVIDIA® GVDB VOXELS

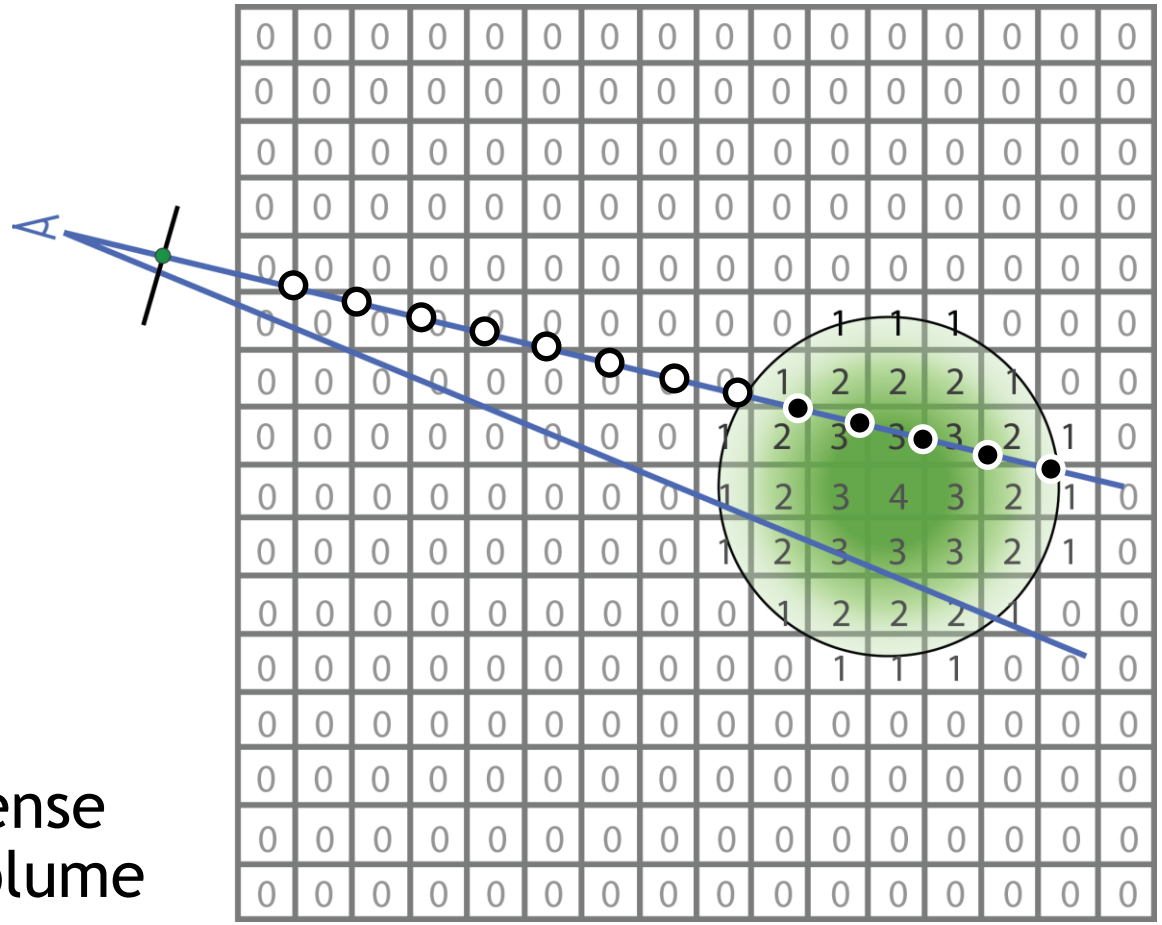
Overview



Dense Volume

NVIDIA® GVDB VOXELS

Overview

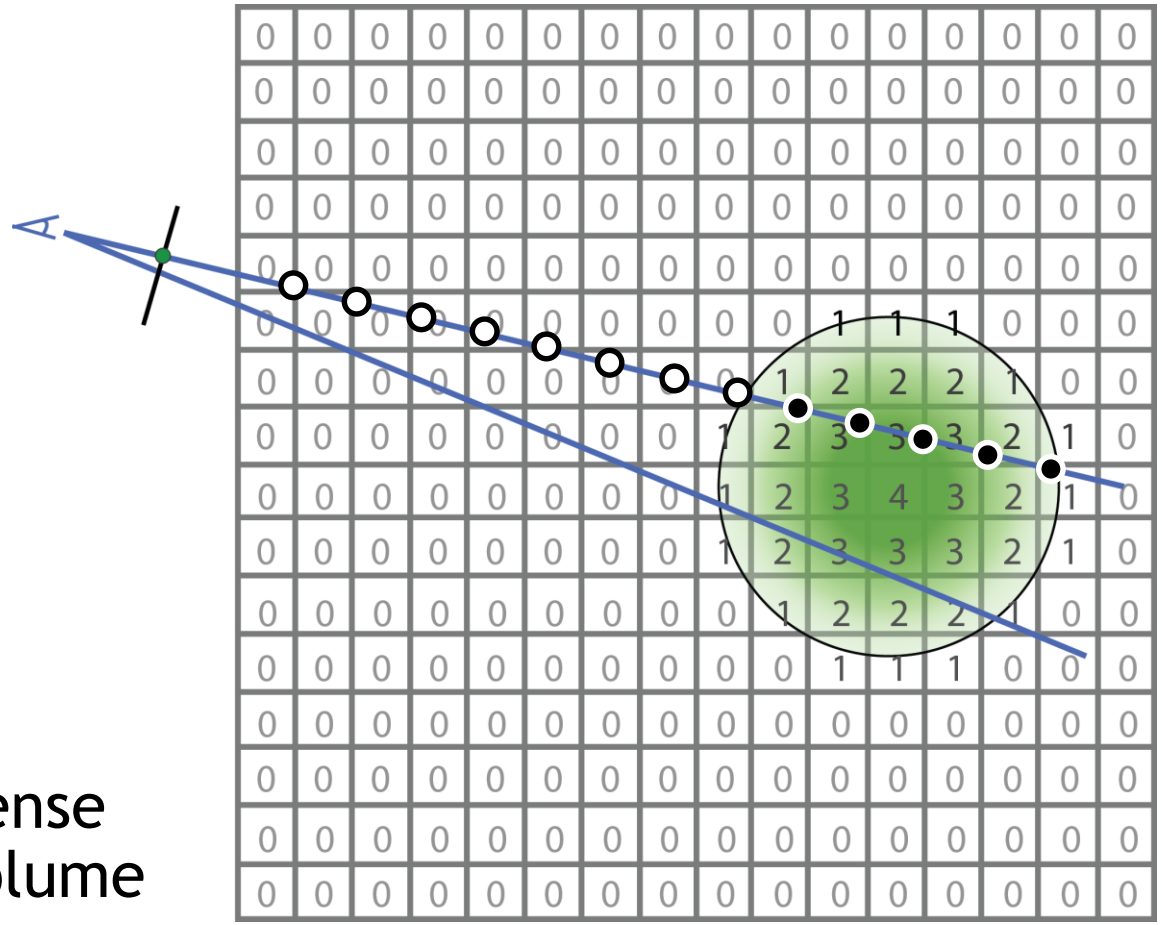


Dense Volume

- ○ 8 empty steps
- • 5 sample steps

NVIDIA® GVDB VOXELS

Overview

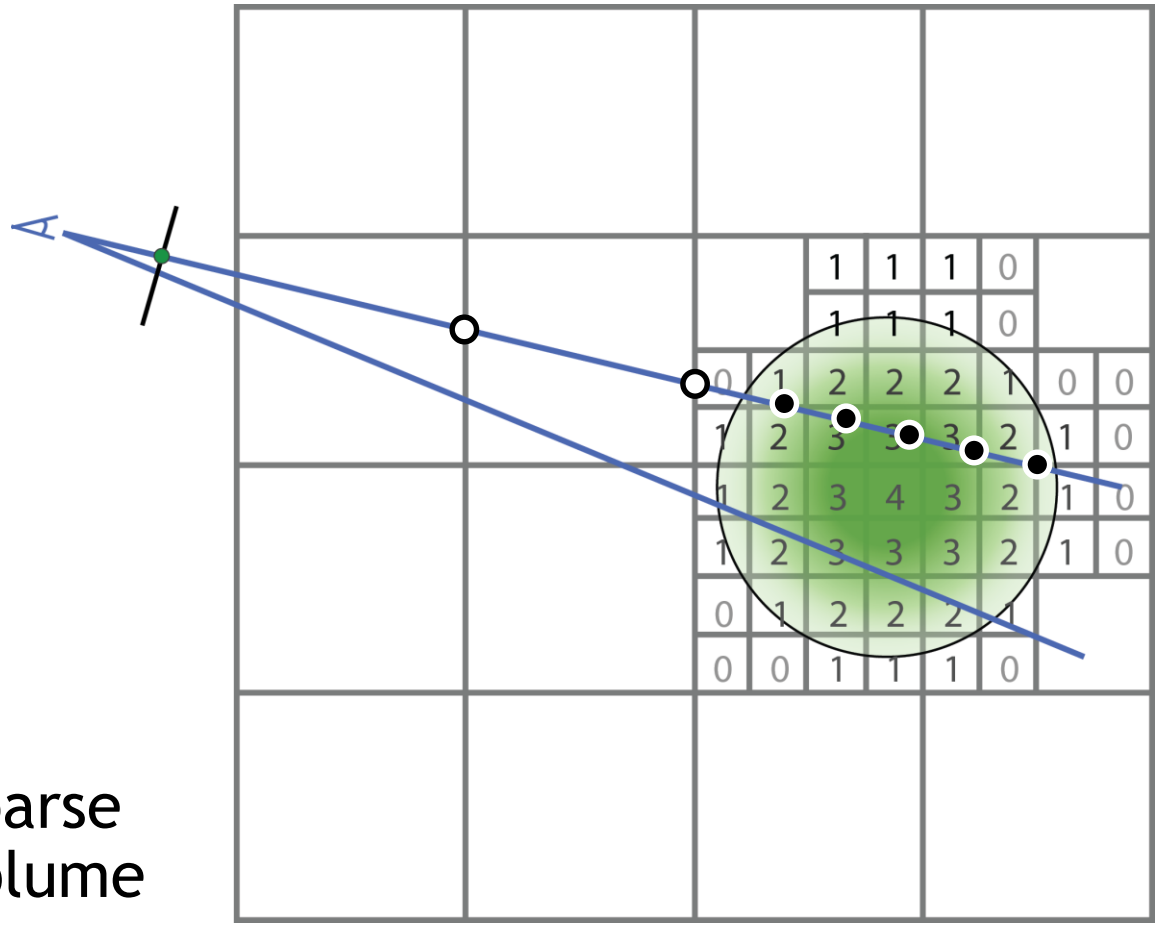


Dense Volume

- ○ 8 empty steps
- • 5 sample steps

NVIDIA® GVDB VOXELS

Overview

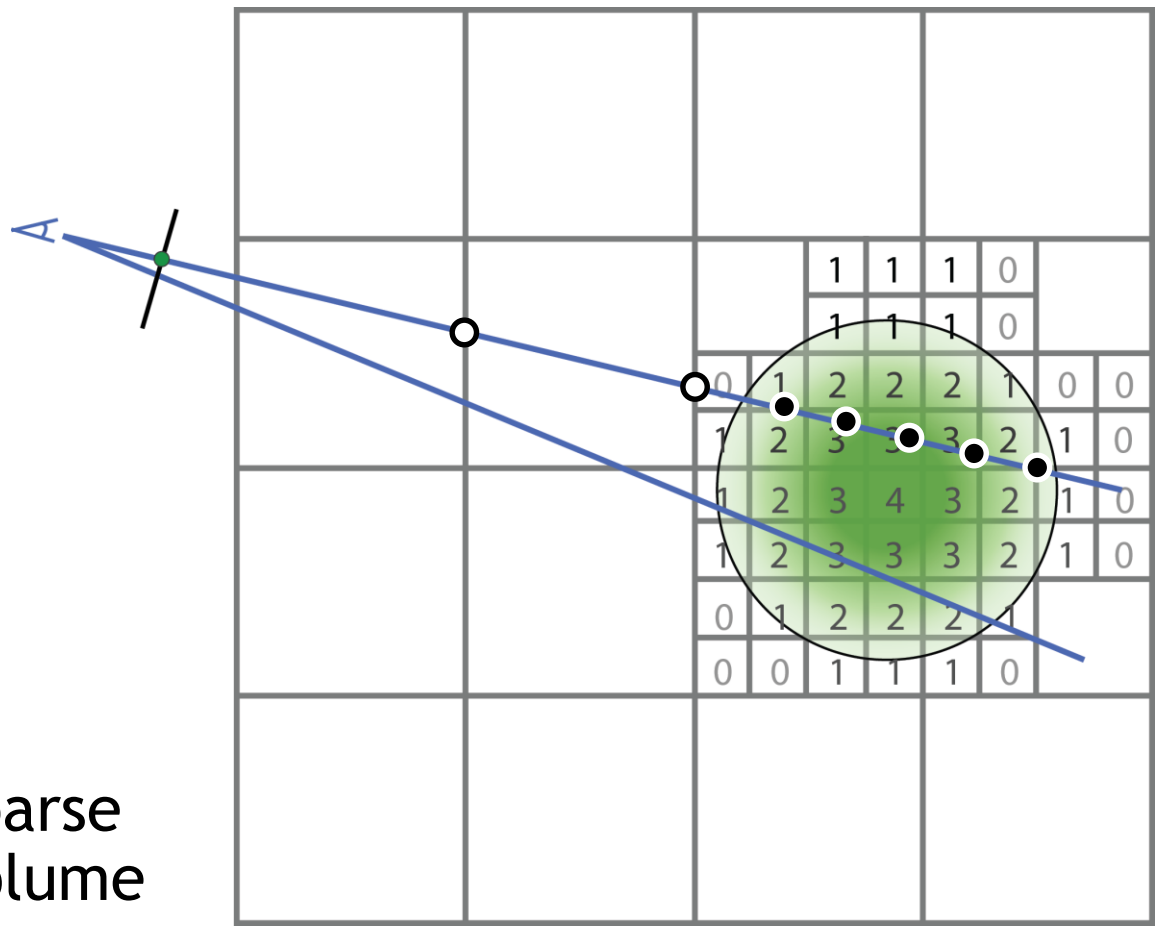


Sparse Volume

- ○ 2 DDA skip steps
- • 5 sample steps

NVIDIA® GVDB VOXELS

Overview

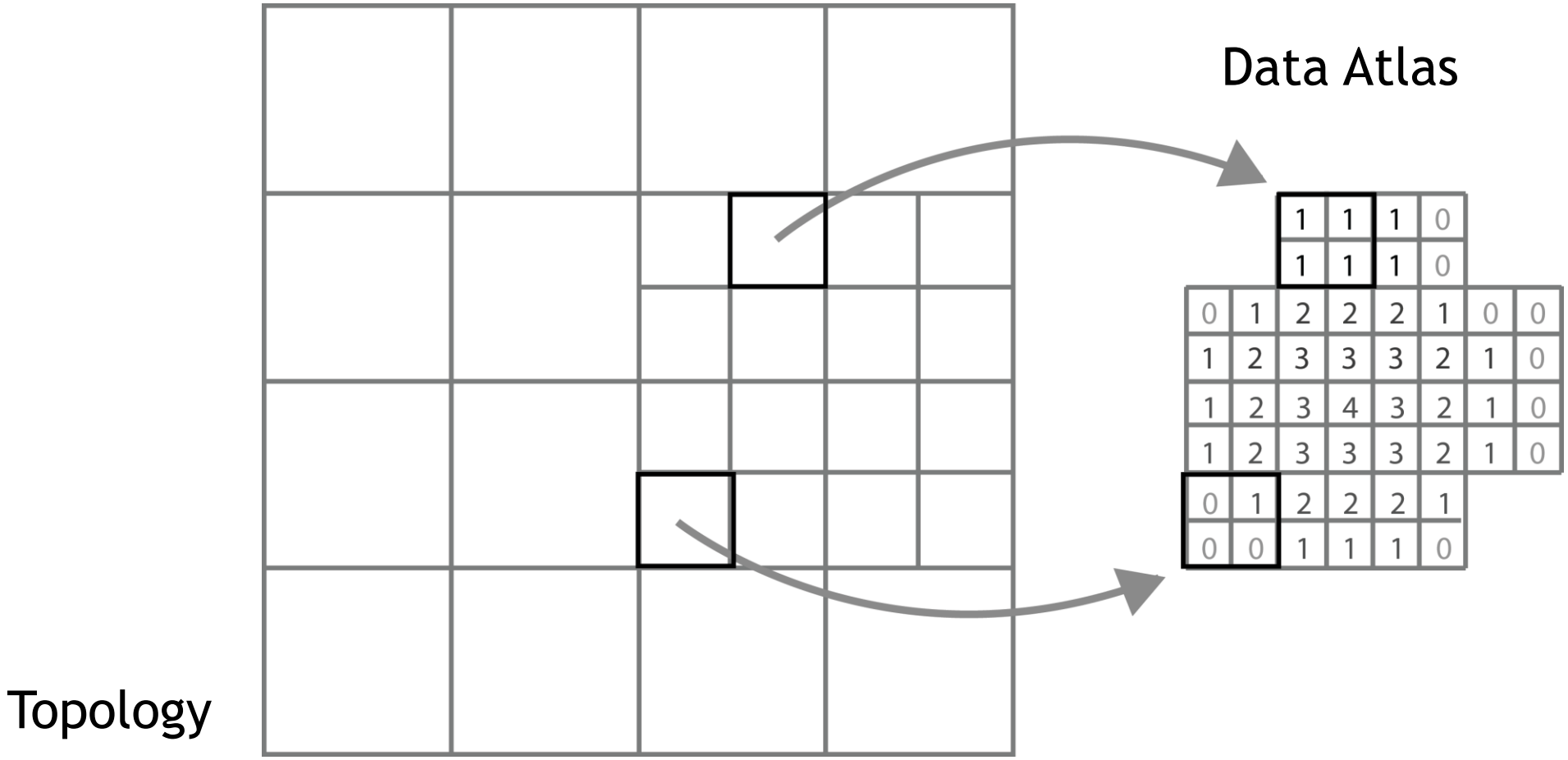


Sparse Volume

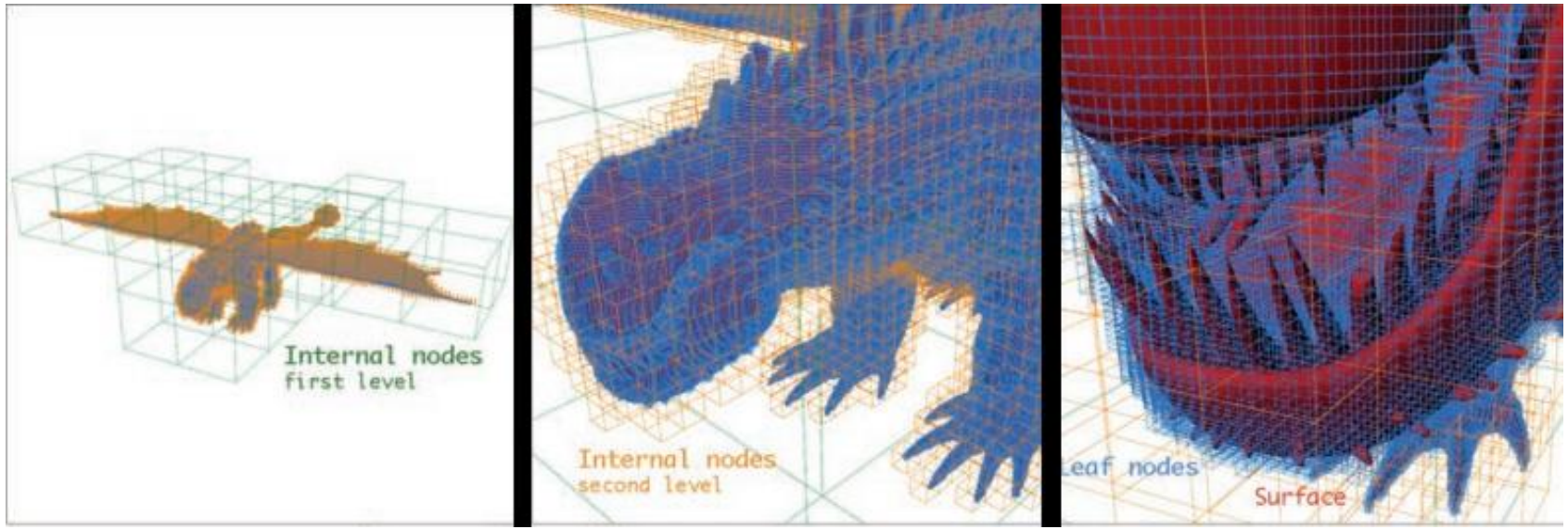
- ○ 2 DDA skip steps
- • 5 sample steps

NVIDIA® GVDB VOXELS

Overview



OPENVDB



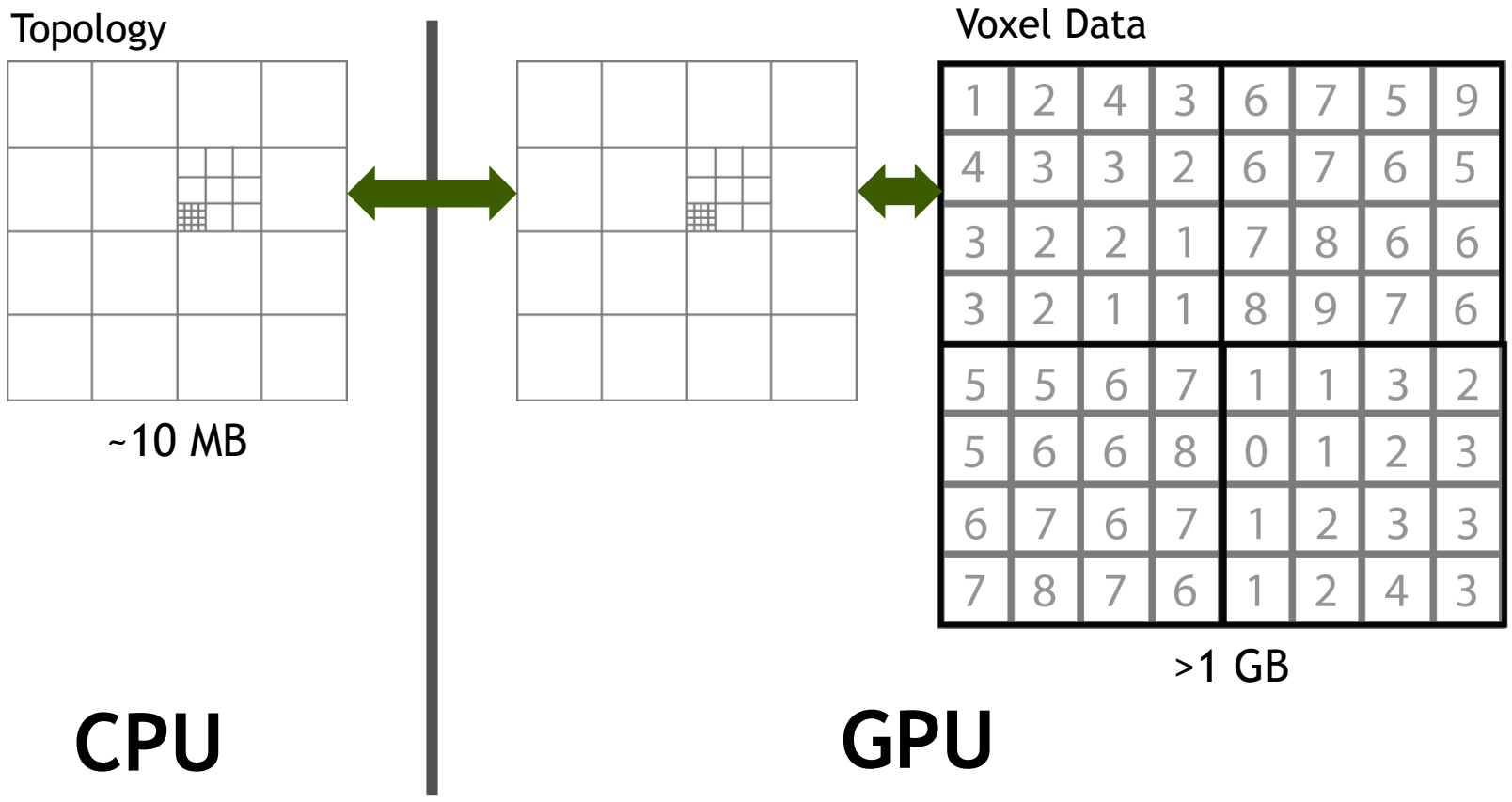
OpenVDB www.openvdb.org

Ken Museth, *Dreamworks Animation*
VDB: High-Resolution Sparse Volumes
with Dynamic Topology.
Transactions on Graphics, 2013

Houdini 3D Animation Tools
REALFLOW
MODO
PIXAR'S RenderMan
clarisse
v·ray
Guerilla Render
octanerender
arnold SOLIDANGLE
MAXWELL RENDER
3Delight

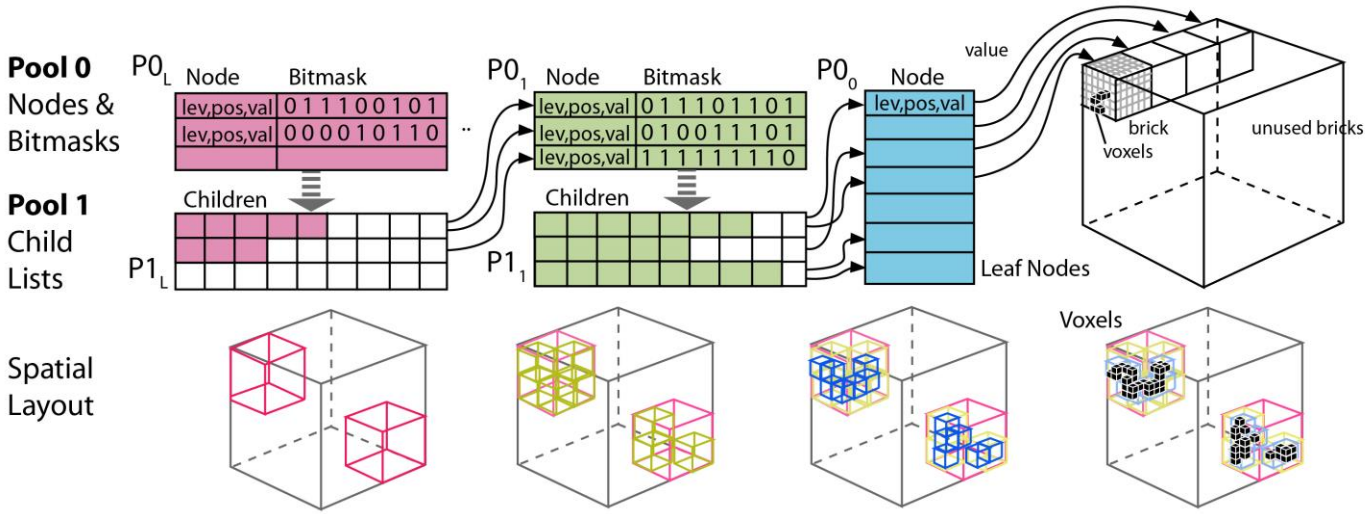
NVIDIA® GVDB VOXELS

Overview



NVIDIA® GVDB VOXELS

Overview



Hoetzlein, GVDB: Raytracing Sparse Voxel Database Structures on the GPU
High Performance Graphics, 2017

- Memory pooling for fast topology
- 3D Textures for hardware trilinear filtering
- Indexing instead of pointers for CPU-GPU transfers

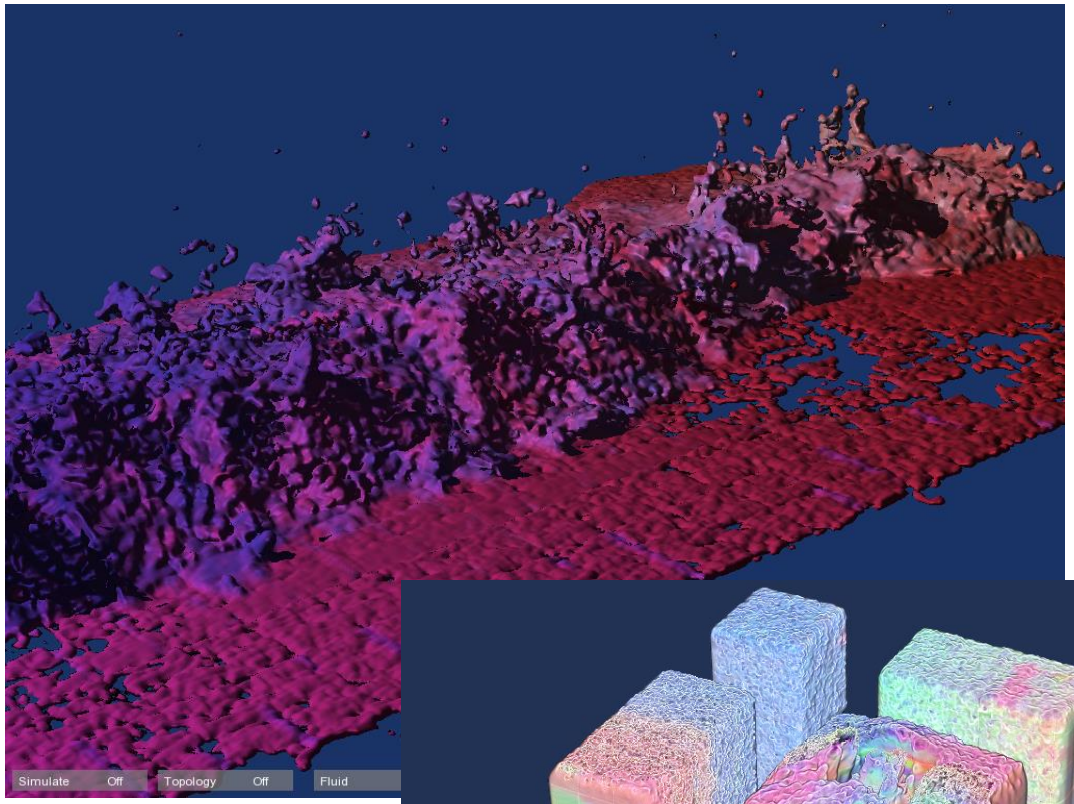
NVIDIA® GVDB VOXELS

Features
for Developers

Compute API	Author compute kernels more easily with *virtual neighbors*.
Render API	Built-in and custom rendering for CUDA and OptiX Raytracing
Dynamic API	Modify topology to support dynamic simulations

See *Programming Guide* for additional APIs and features

COMPUTE / SIMULATION



FluidSurface Sample

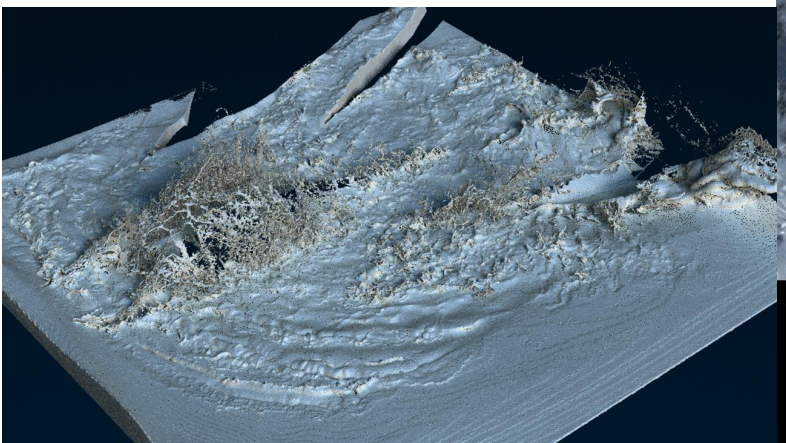
SprayDeposit Sample

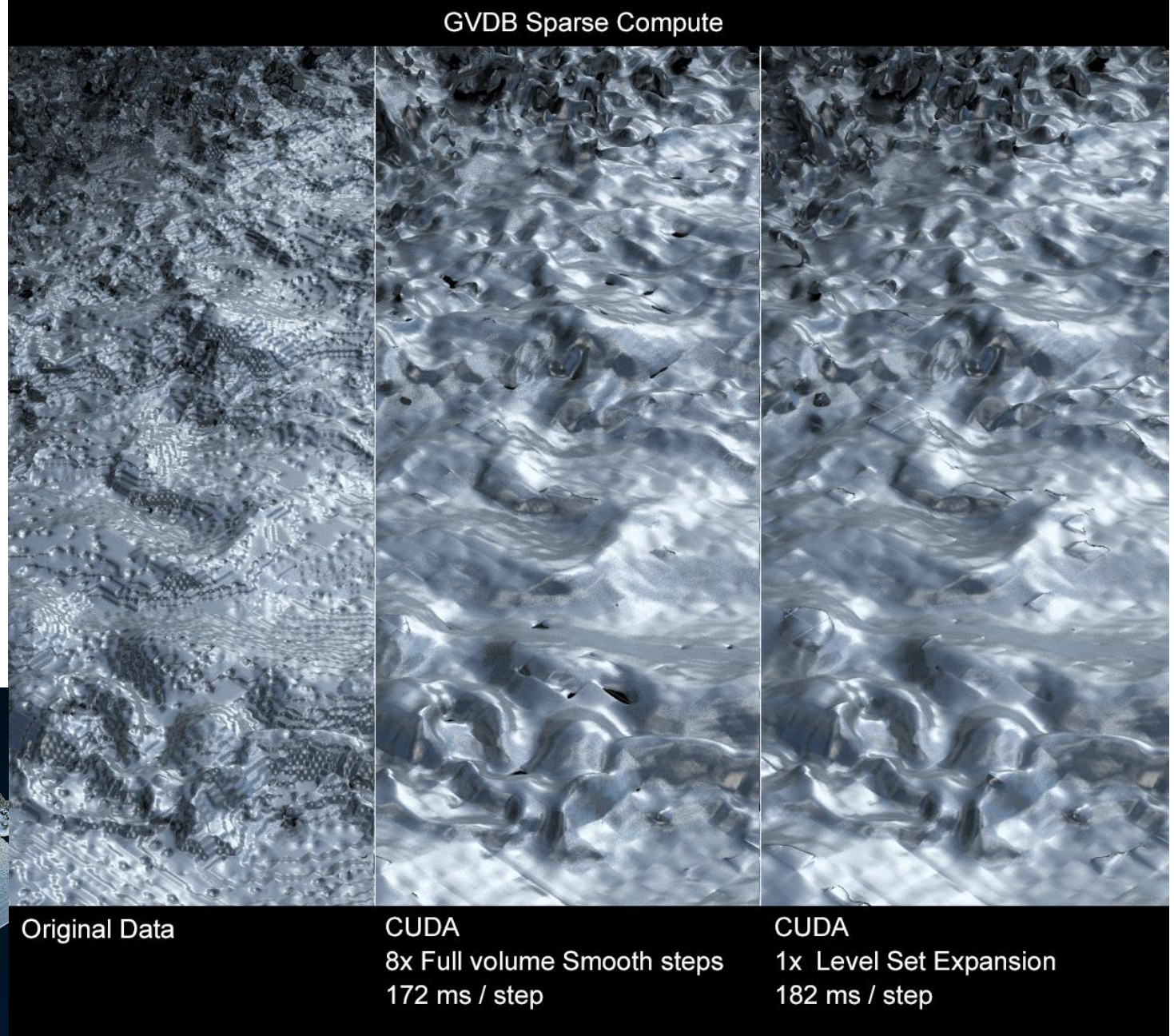
COMPUTE API

Volume Smoothing

Launch GPU kernels over all sparse voxels.

Efficient compute on very large domains.





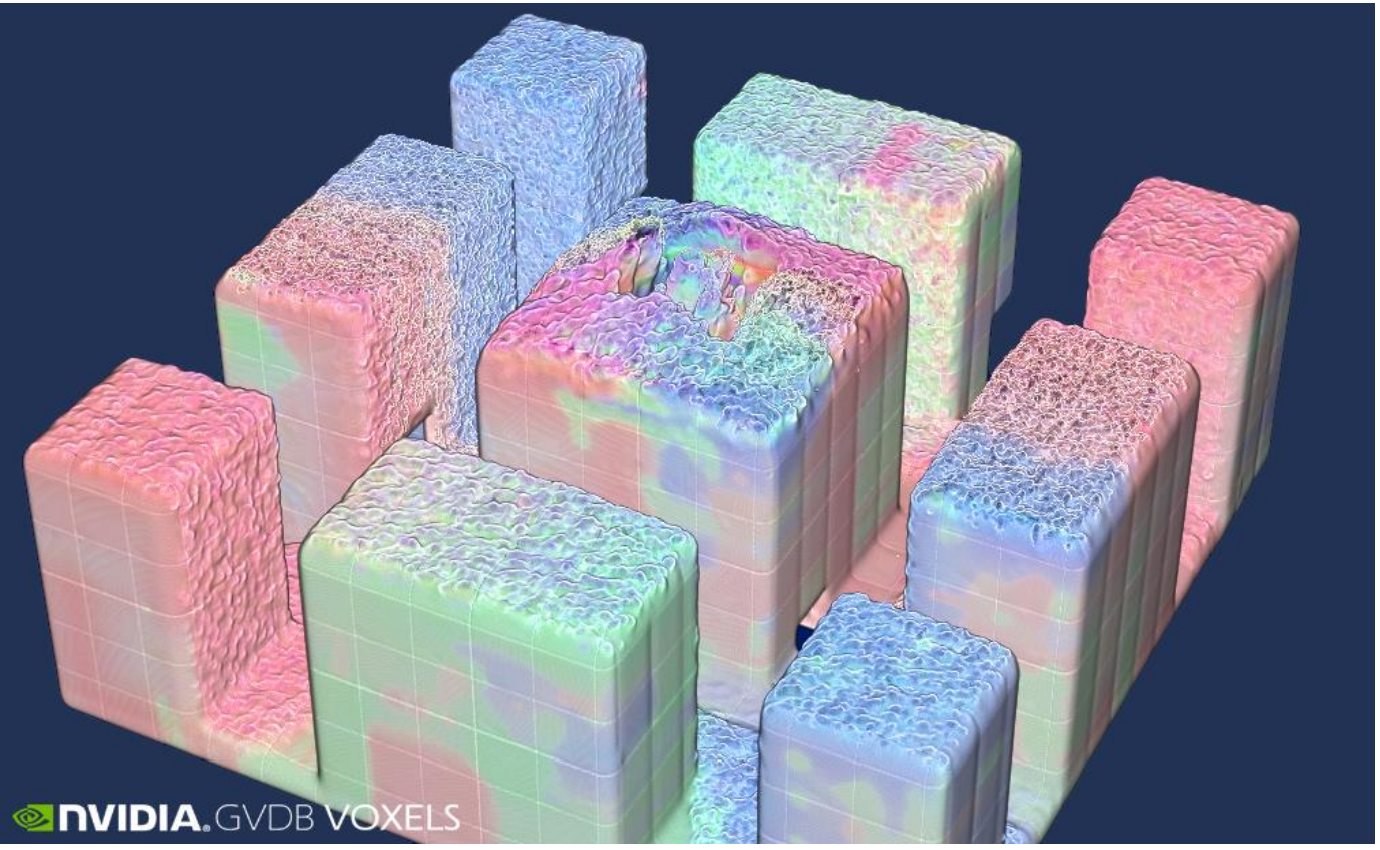
COMPUTE API

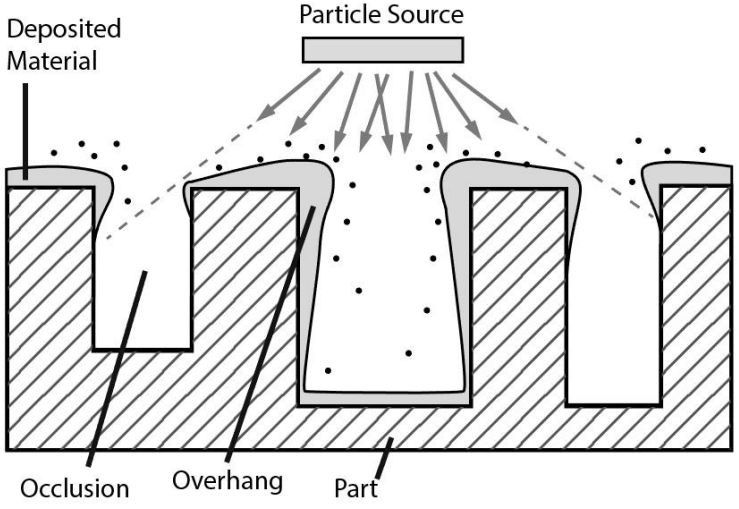
Volume Smoothing

```
extern "C" __global__ void kernelSmooth ( int res, float amt )
{
        GVDB_SHARED_COPY                                    ← Macro ensures neighbors are available in shared memory

        float v = 6.0*svox[ndx.x][ndx.y][ndx.z];            ← Smoothing operation
        v += svox[ndx.x-1][ndx.y][ndx.z];                       ( values from neighbors)
        v += svox[ndx.x+1][ndx.y][ndx.z];
        v += svox[ndx.x][ndx.y-1][ndx.z];
        v += svox[ndx.x][ndx.y+1][ndx.z];
        v += svox[ndx.x][ndx.y][ndx.z-1];
        v += svox[ndx.x][ndx.y][ndx.z+1];
        v /= 12.0;

        surf3Dwrite ( v, volTexOut, vox.x*sizeof(float), vox.y, vox.z );    ← Output value
}
```

COMPUTE API

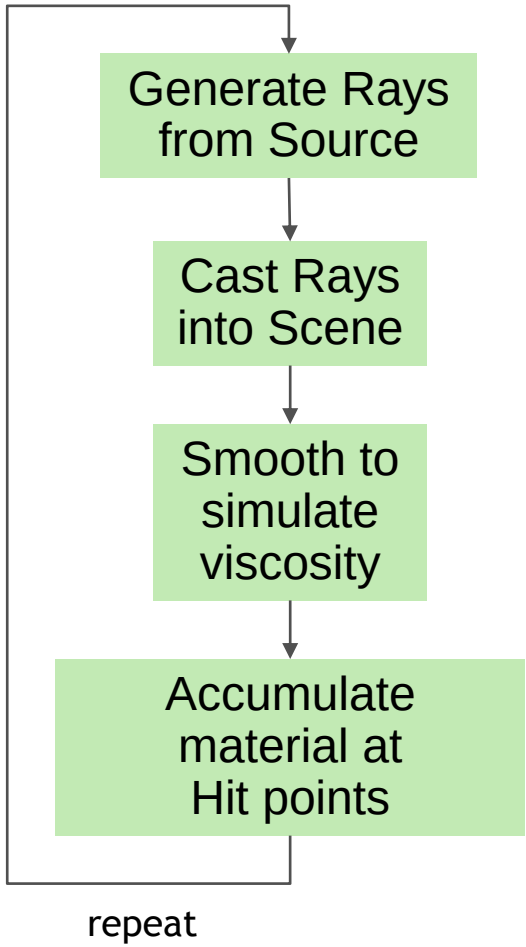
Simulation

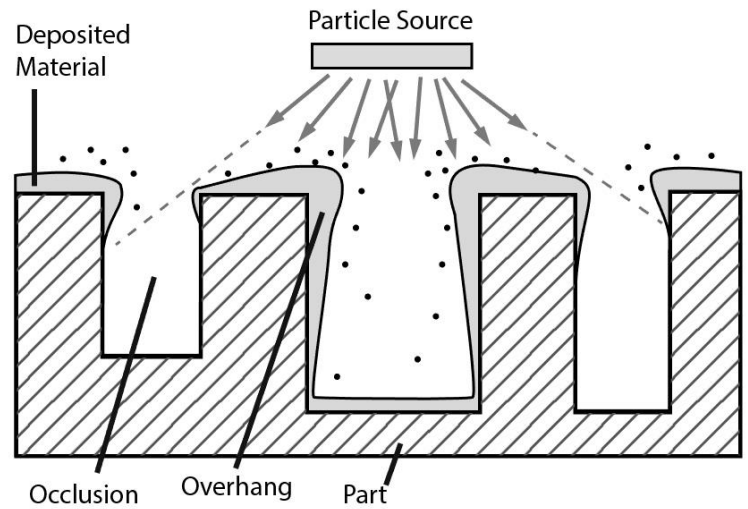




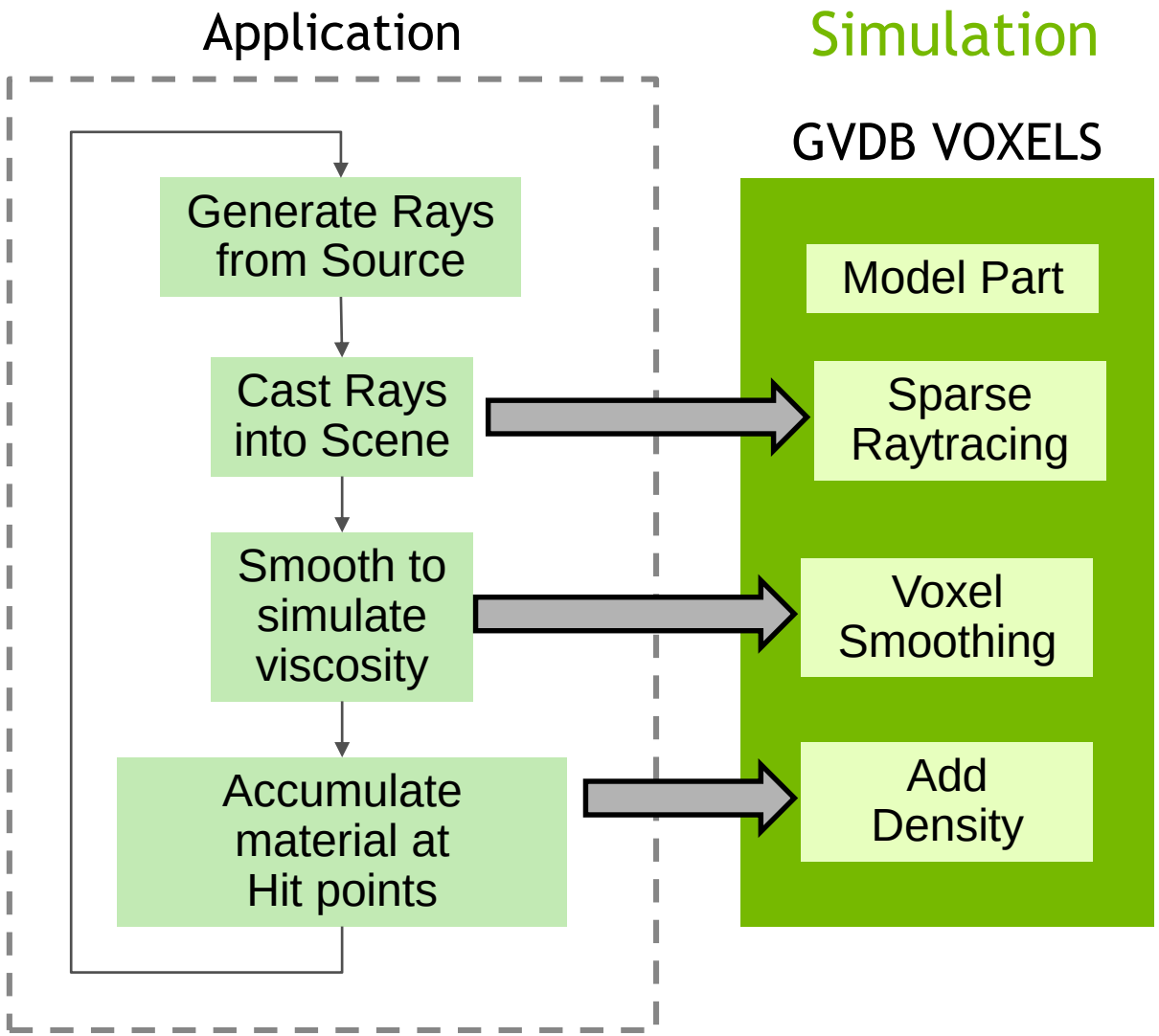
COMPUTE API

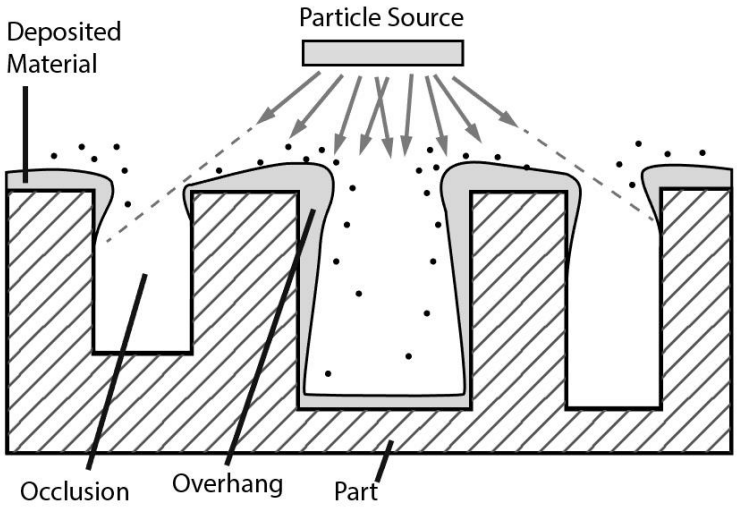
Simulation





COMPUTE API


Application
Simulation
GVDB VOXELS
Generate Rays from Source
Cast Rays into Scene
Smooth to simulate viscosity
Accumulate material at Hit points
Model Part
Sparse Raytracing
Voxel Smoothing
Add Density


Deposited Material
Particle Source
Occlusion
Overhang
Part

COMPUTE API

Simulation

```
void App::simulate ()
{
        numrays = 1000;
        gvdb.AllocData ( rays,  numrays, sizeof(ScnRay) );

        ScnRay* ray = (ScnRay*) gvdb.getDataPtr ( 0, rays );
        for (int n=0; n < numrays; n++ ) {
                GenerateRay ( ray );
                ray++;
        }
        gvdb.CommitData ( rays );

        gvdb.Raytrace ( rays, SHADE_TRILINEAR, 0, -0.0001 );

        gvdb.SetPoints ( pntpos, pntclr );
        gvdb.InsertPoints ( rays, Vector3DF(0,0,0) );

        gvdb.ScatterPointDensity ( rays, 2.0, 1.0, Vector3DF(0,0,0) );
        gvdb.UpdateApron ();

        gvdb.Compute ( FUNC_SMOOTH, 0, 1, Vector3DF(4,0,0), true );
}
```

← Allocate ray memory (CPU and GPU)

← Generate rays

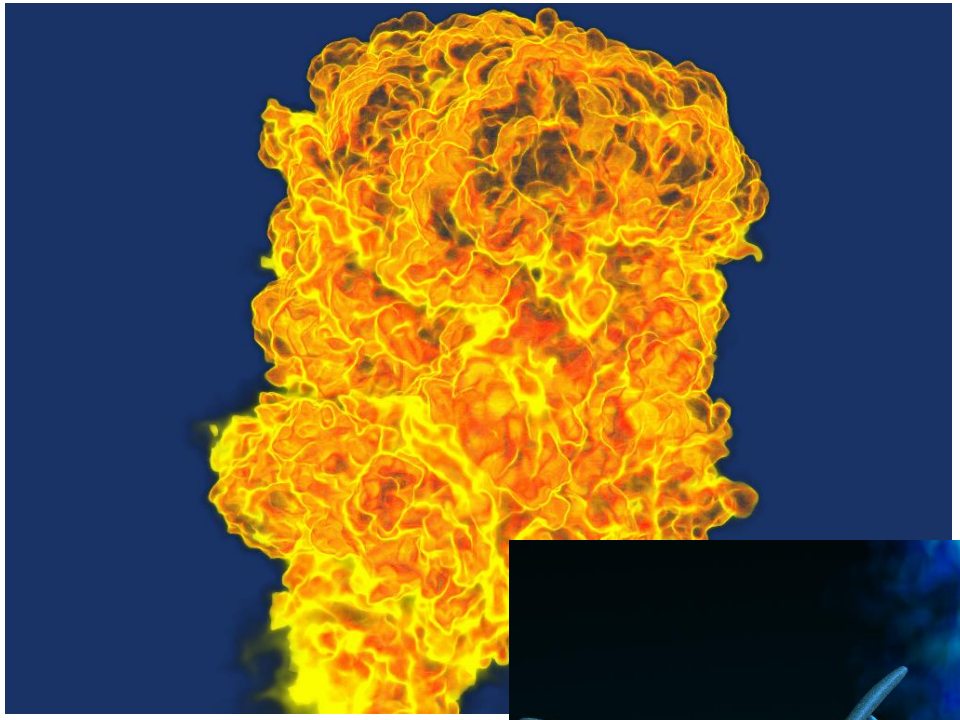
← Commit rays to GPU

← Raytracing to hit part

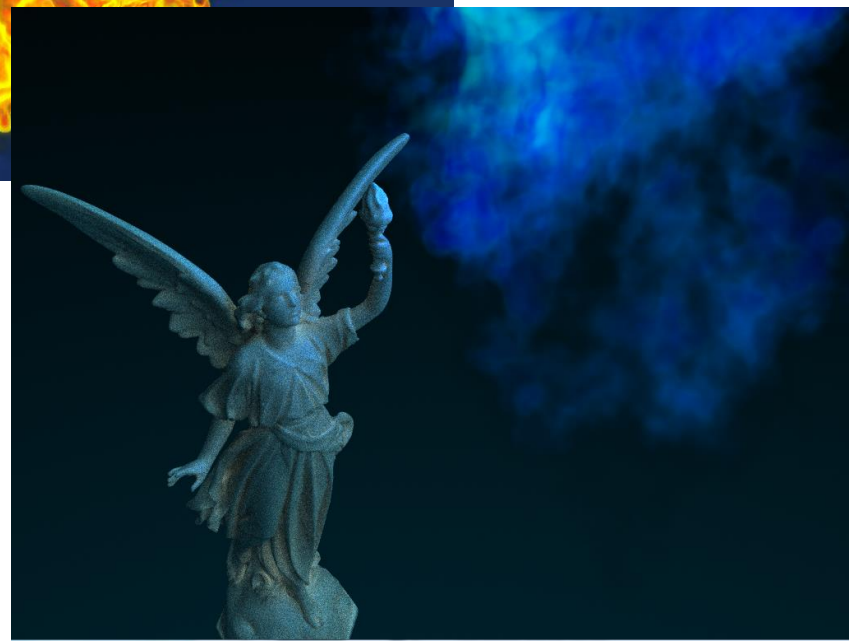
← Scatter new material at hit points

← Smooth result slightly

RENDERING



InteractiveGL Sample



InteractiveOptiX Sample

RENDER API

Native Rendering

```
// Render with CUDA
gvdb.Render ( 0,  SHADE_TRILINEAR, .. )

// Read result into OpenGL texture
gvdb.ReadRenderTexGL ( 0, gl_texture );

// Display texture on screen
renderScreenQuadGL ( gl_texture );
```

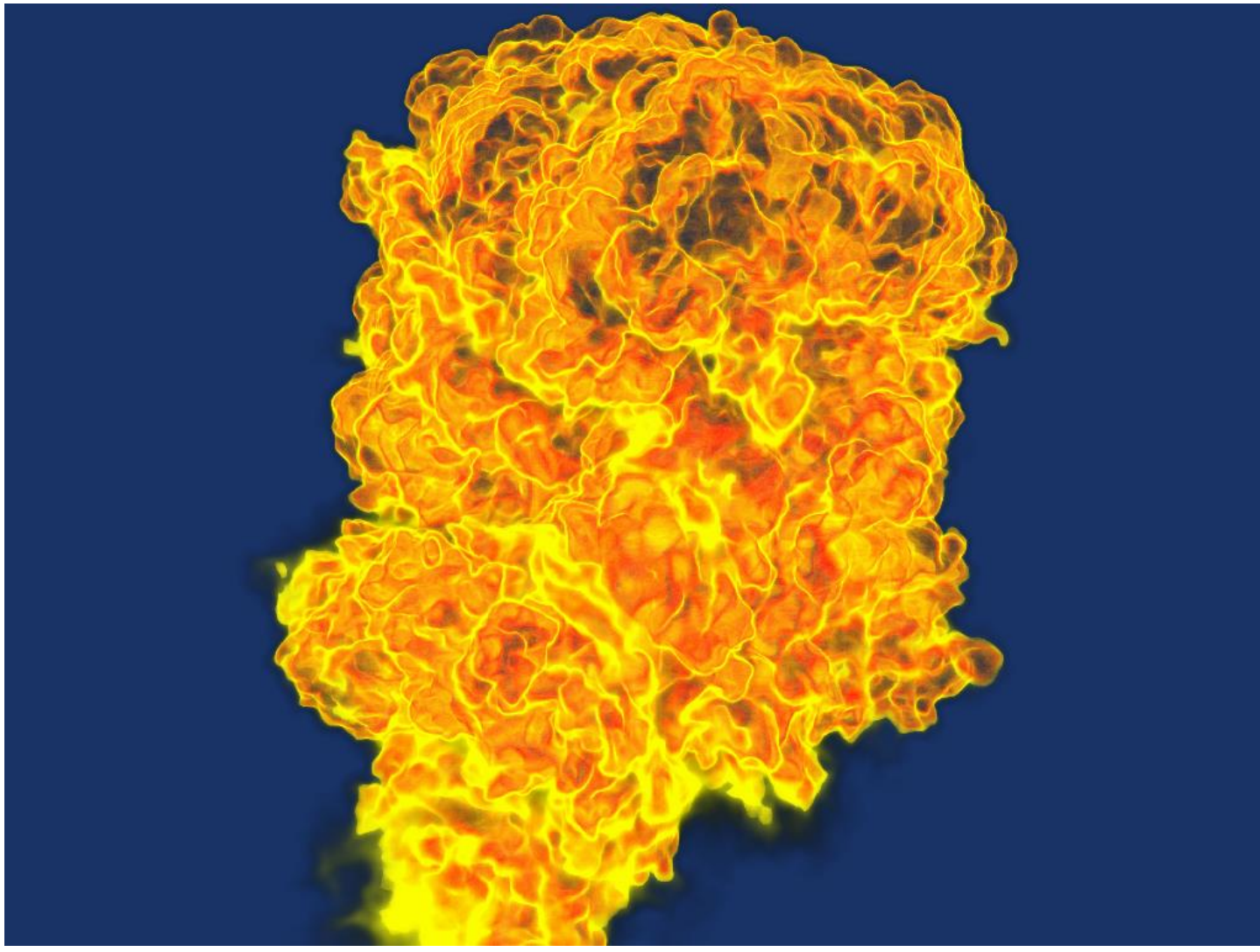
3DPrint Sample

RENDER API

Native Rendering

```
// Set render parameters
SetExtinct ( -1.0f, 1.5f, 0.0f );
SetVolumeRange ( 0.1f, 0.0f, .1f );
SetCutoff ( 0.005f, 0.01f, 0.0f );
SetBackgroundClr ( 0.1, 0.2, 0.4, 1.0 );

// Create transfer function
LinearTransferFunc ( 0.00f, 0.25f, … );
LinearTransferFunc ( 0.25f, 0.50f, … );
LinearTransferFunc ( 0.50f, 0.75f, … );
LinearTransferFunc ( 0.75f, 1.00f, … );
```

```
// Render with CUDA
gvdb.Render ( 0,  SHADE_VOLUME, .. )
```



InteractiveGL Sample

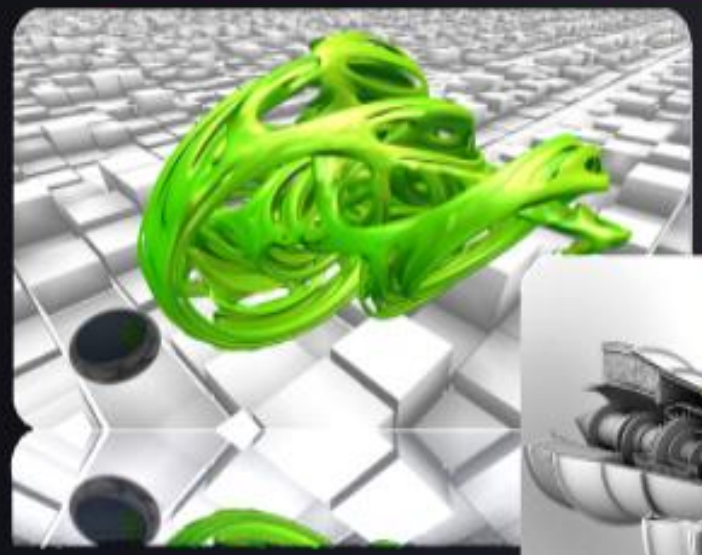
OptiX: A General Purpose Ray Tracing Engine

OptiX: A General Purpose Ray Tracing Engine, Steven Parker. ACM Transactions on Graphics, Vol. 29, No. 4, July 2010

NVIDIA® DESIGNWORKS™

OptiX SDK

- Available for free: Windows, Linux, Mac
- http://developer.nvidia.com



RENDER API

GVDB and OptiX

InteractiveOptiX Sample

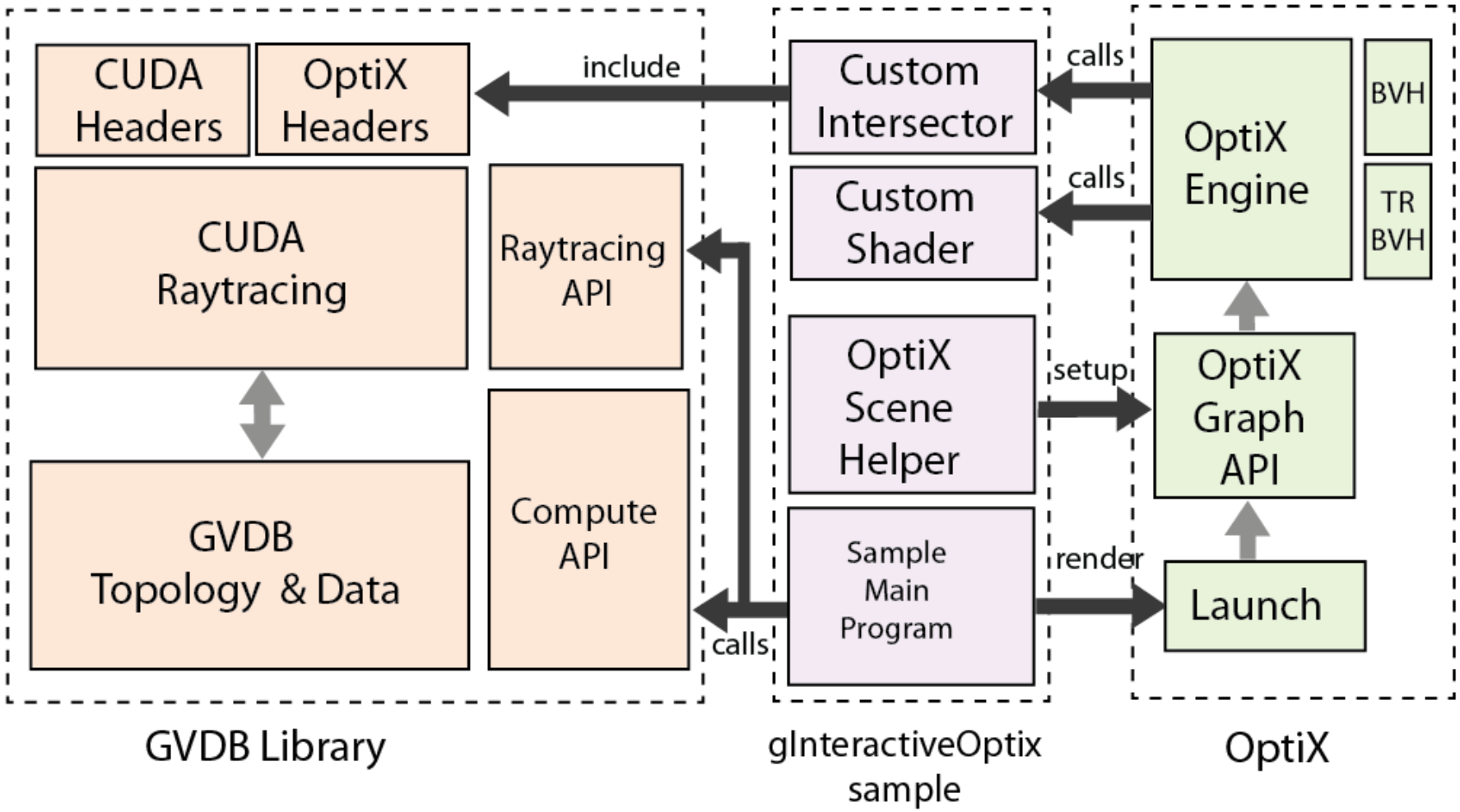
RENDER API

GVDB and OptiX

InteractiveOptiX Sample

RENDER API

GVDB and OptiX



RENDER API

GVDB and OptiX

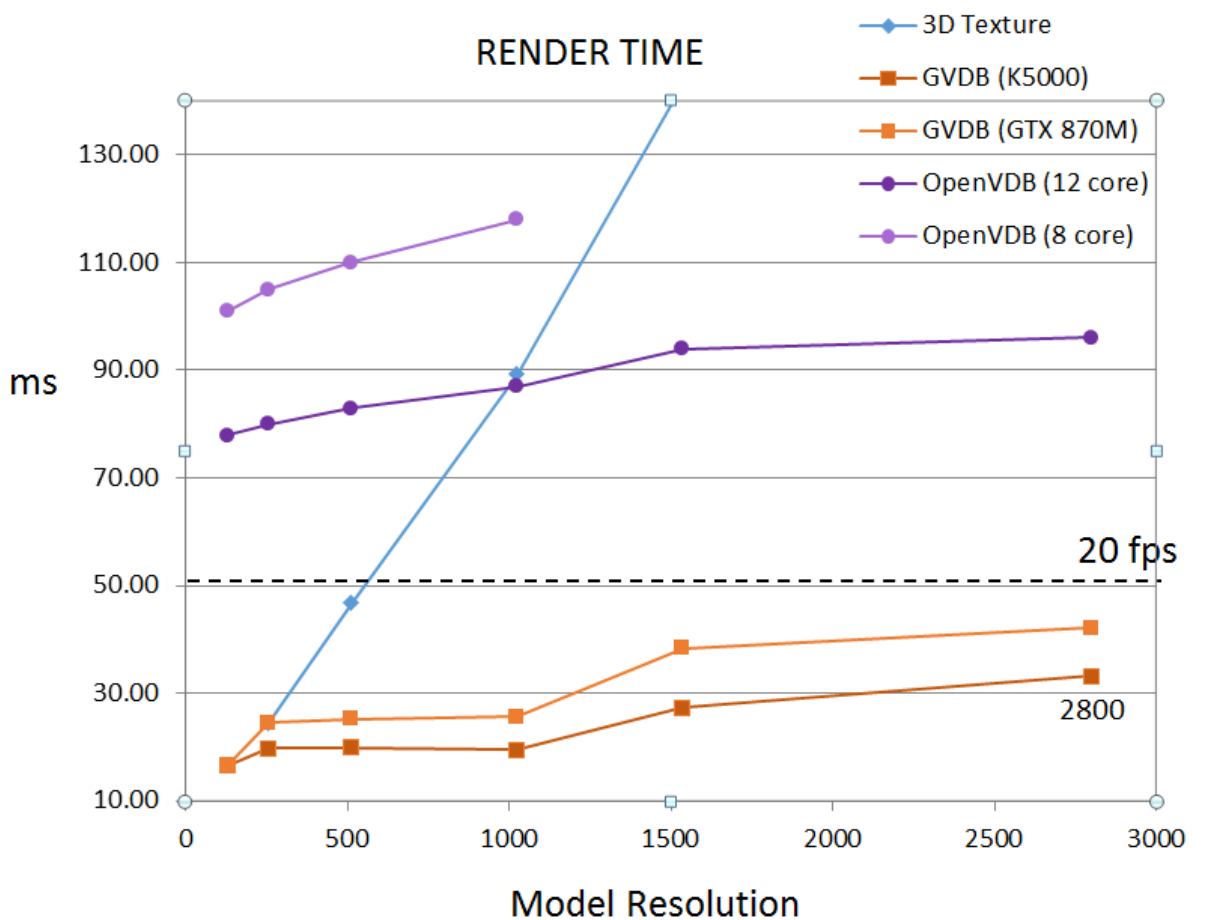
Thursday, 2:00-2:25pm, S7425

3D PRINTING WITH NVIDIA
GVDB VOXELS

RENDER API

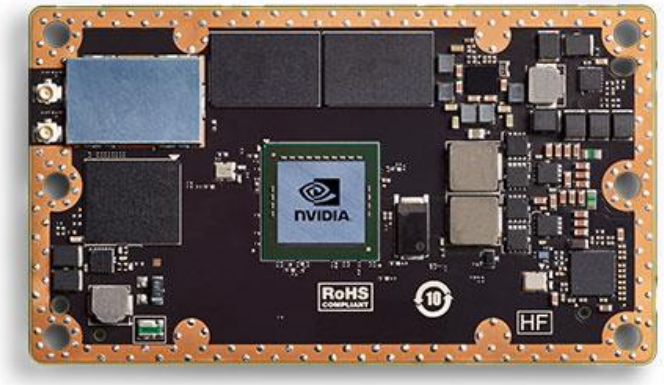
Features

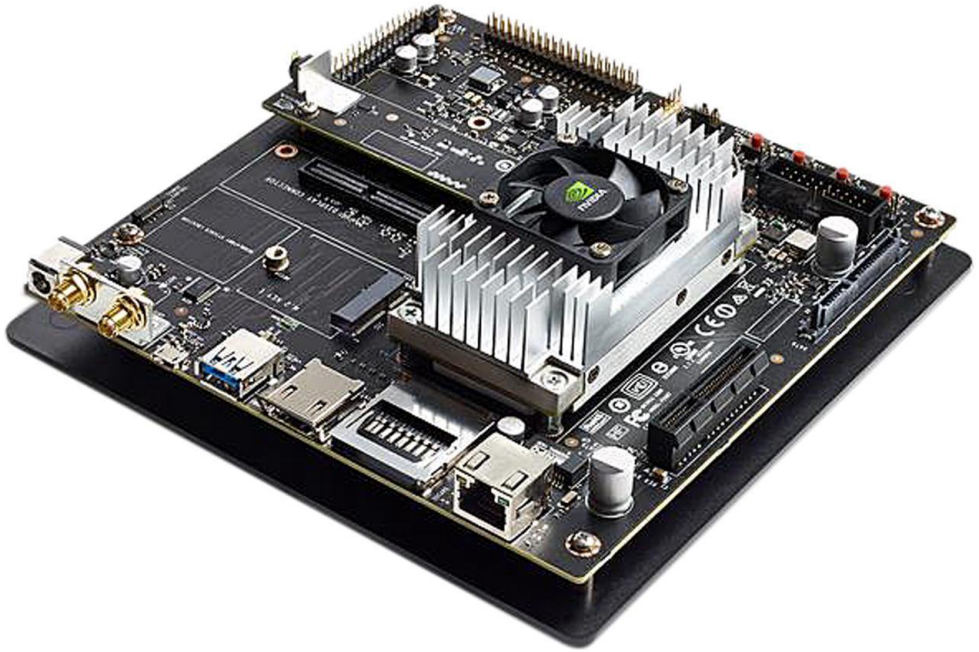
- Efficient raytracing of large, sparse volumes
- CUDA based raytracing
- Native rendering of semi-transparent volumes, isosurfaces and level sets
- Integration with NVIDIA® OptiX
- Custom transfer functions and custom render kernels
- Rendering API in GVDB Library



VIDEO

PLATFORMS

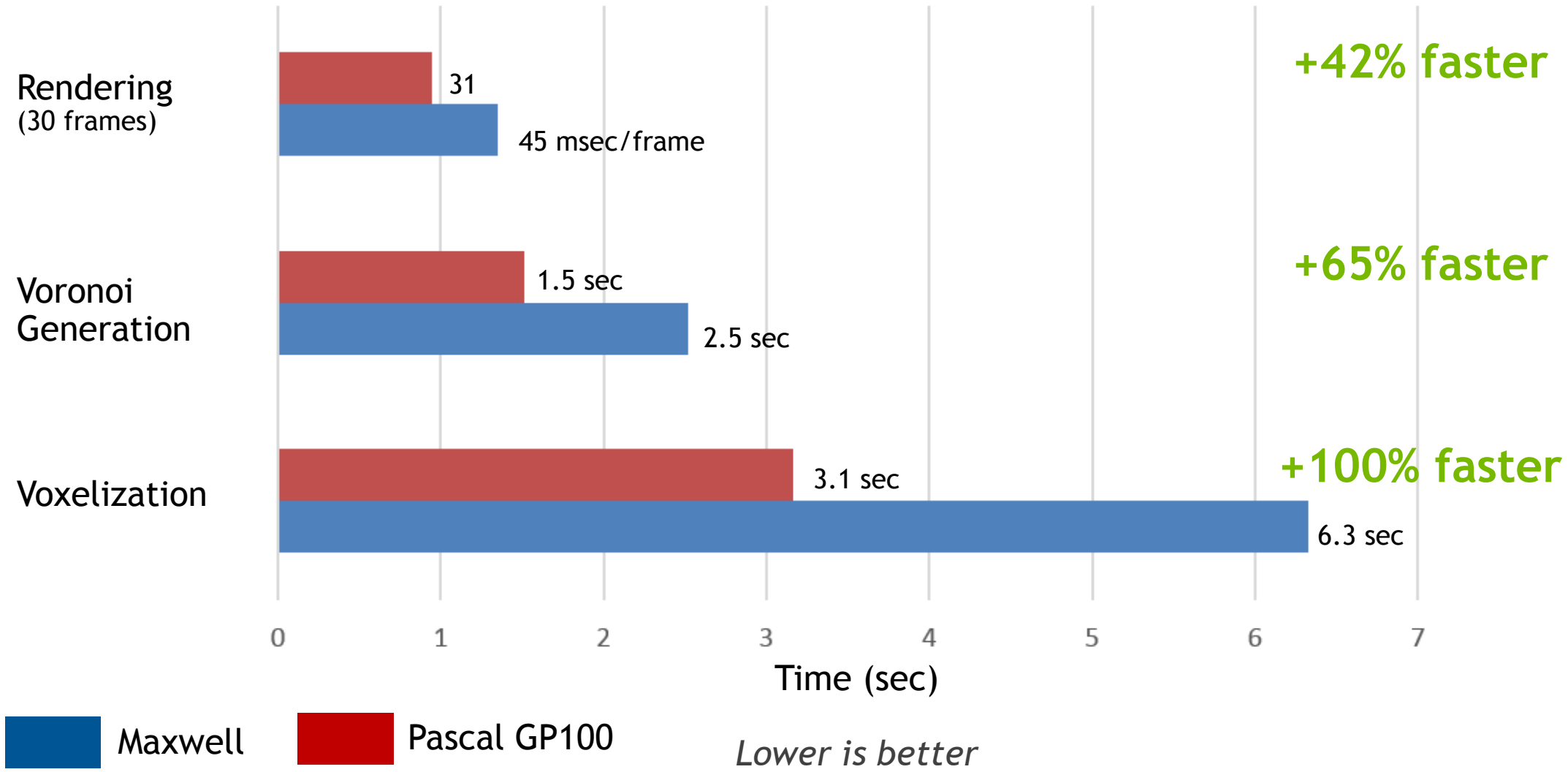




Jetson TX1 / TX2

PASCAL GP100

GVDB Performance

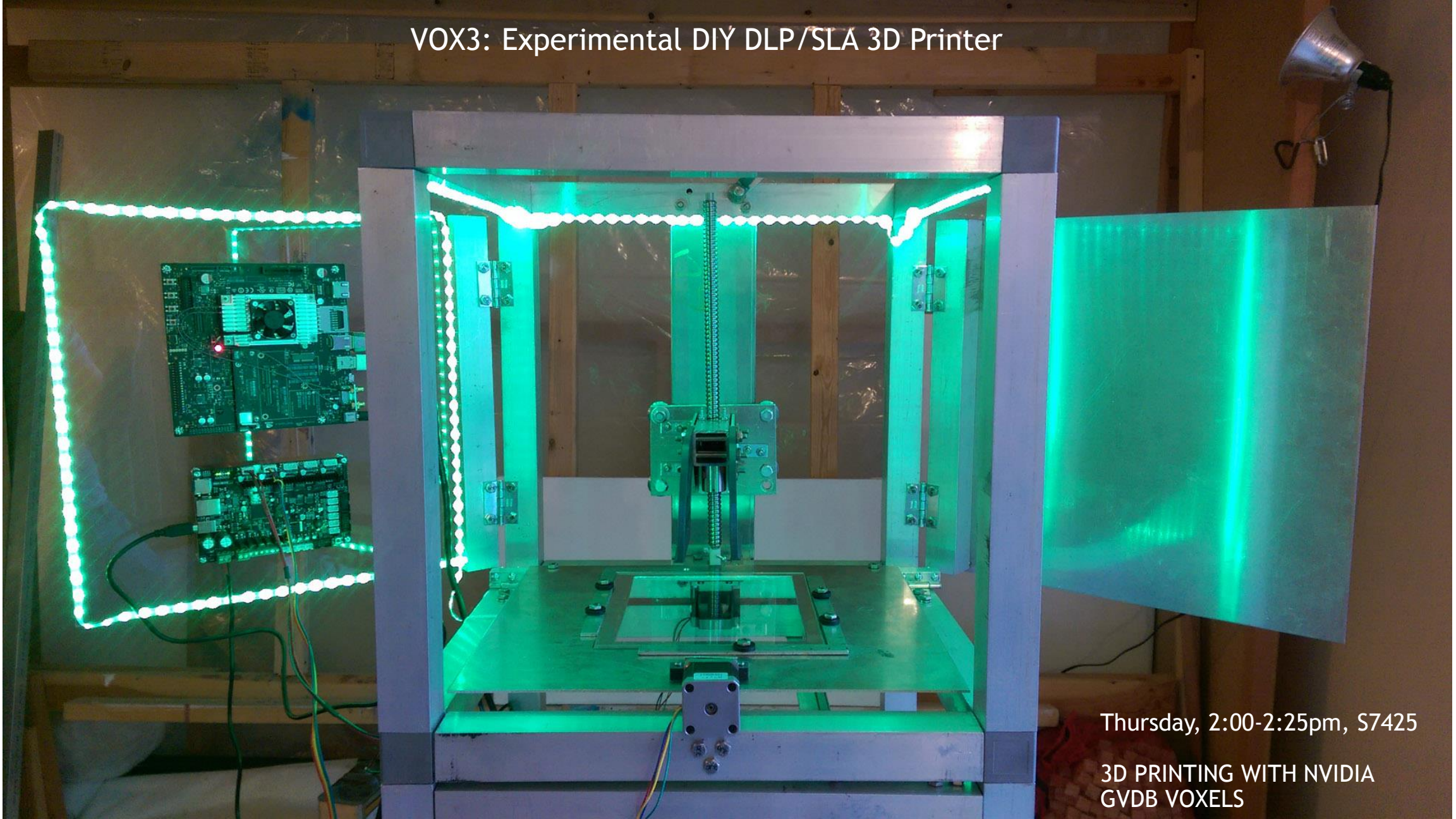


NVIDIA® GVDB VOXELS

Platforms

Hardware:	Jetson TX1 / TX2 embedded systems	*256* cores	(Tegra)
	Quadro, GeForce	*3840* cores	(GP100)
	Tesla K80 computing cluster	*4992* cores	(K80)
Software:	CUDA Compute 3.0 and higher		
	CUDA Toolkit 6.5 and higher		
Operating Systems:	Windows 7/8/10 64-bit and Linux		
Licensing:	Open Source, BSD 3-clause		

VOX3: Experimental DIY DLP/SLA 3D Printer



Thursday, 2:00-2:25pm, S7425

3D PRINTING WITH NVIDIA GVDB VOXELS

NVIDIA® GVDB VOXELS

Software

http://developer.nvidia.com/gvdb

Download from website

Windows Installer or Github

Comes with 8x samples

Detailed *Programming Guide* on webpage

New Forum on devtalk.nvidia.com

NVIDIA® GVDB VOXELS

Rama Hoetzlein — Lead Architect for GVDB Voxels
rhoetzlein@nvidia.com

Thanks to..

Andrew Page	Product Manager
Prerna Dogra	Product Manager, 3D Printing
Vincent Brisebois	Marketing
Tristan Lorach	Professional Graphics

THANK YOU