GPU TECHNOLOGY CONFERENCE

April 4-7, 2016 | Silicon Valley

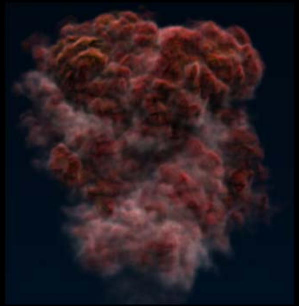
RAYTRACING SCIENTIFIC DATA IN NVIDIA(R) OPTIX™ WITH GVDB SPARSE VOLUMES

Rama Karl Hoetzlein, April 6th 2016

PRESENTED BY NVIDIA

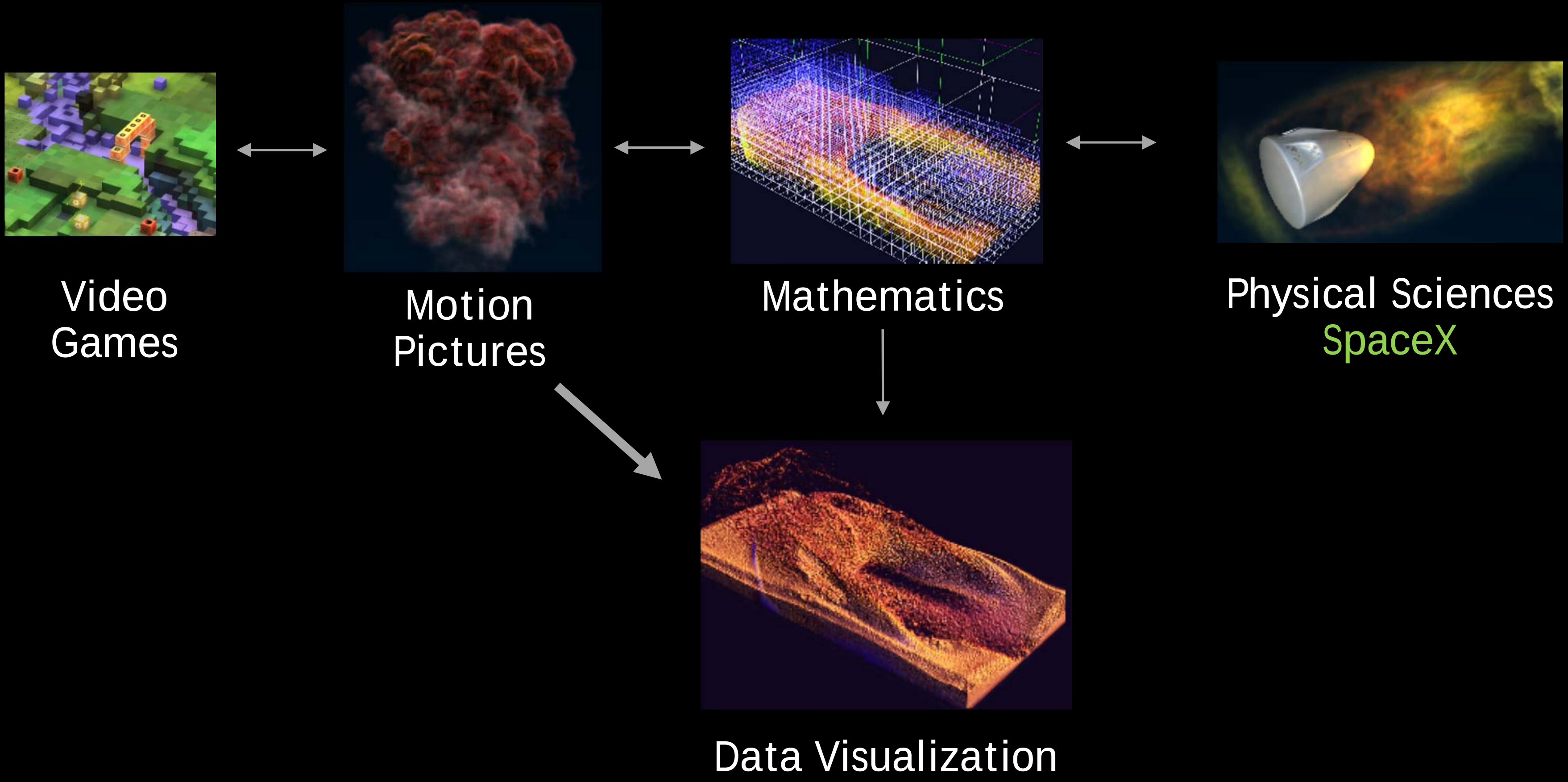
CONVERGENCE

Video
Games

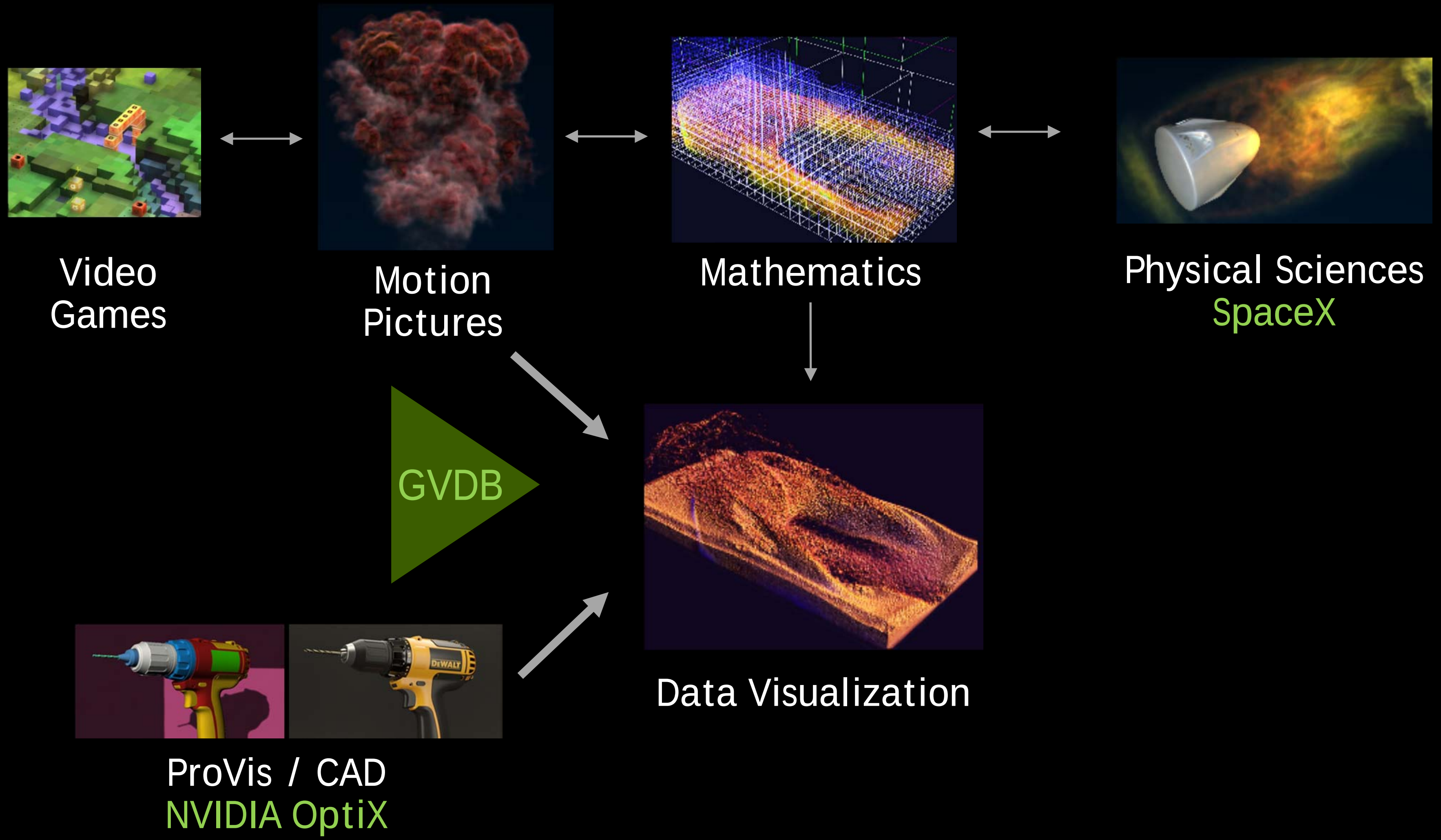


Motion
Pictures

CONVERGENCE



CONVERGENCE

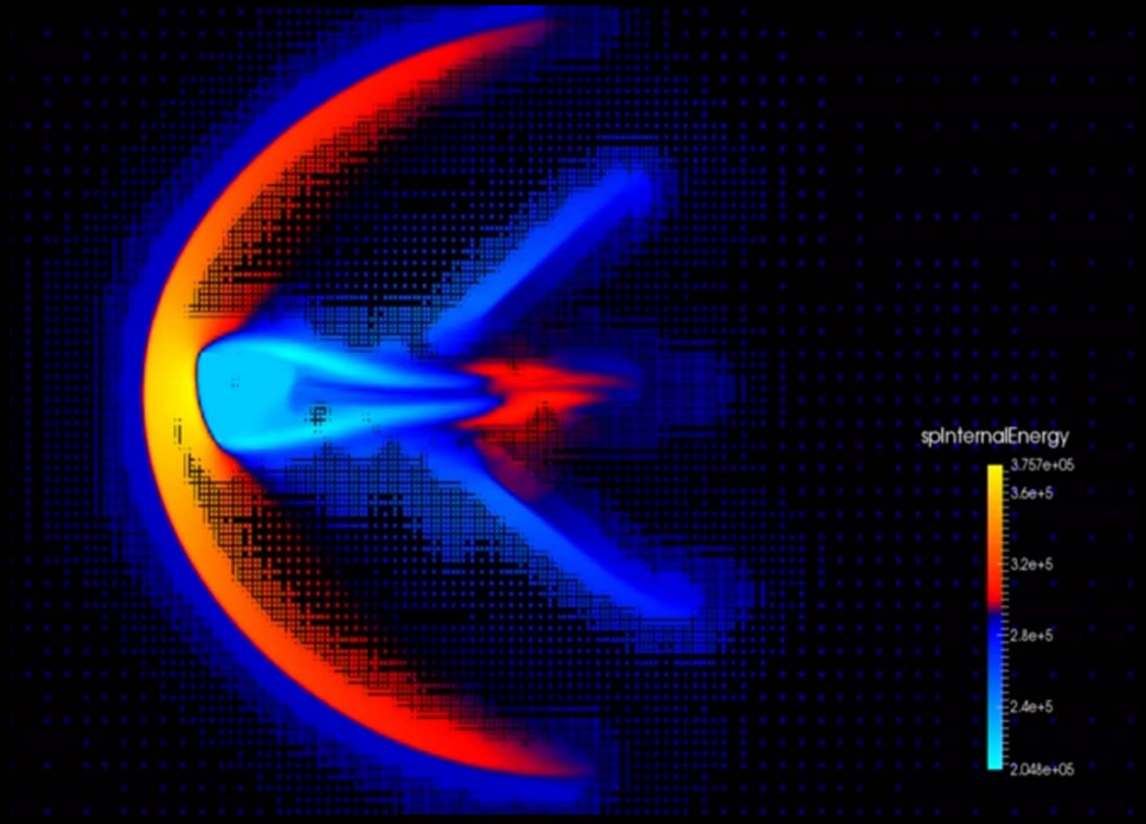


OUTLINE

- Science - SpaceX
- Volume Visualization
- Motion Pictures – OpenVDB
- Provis Graphics – NVIDIA OptiX
- GVDB Sparse Volumes
- Results

SPACEX

Wavelet Simulation Source Data

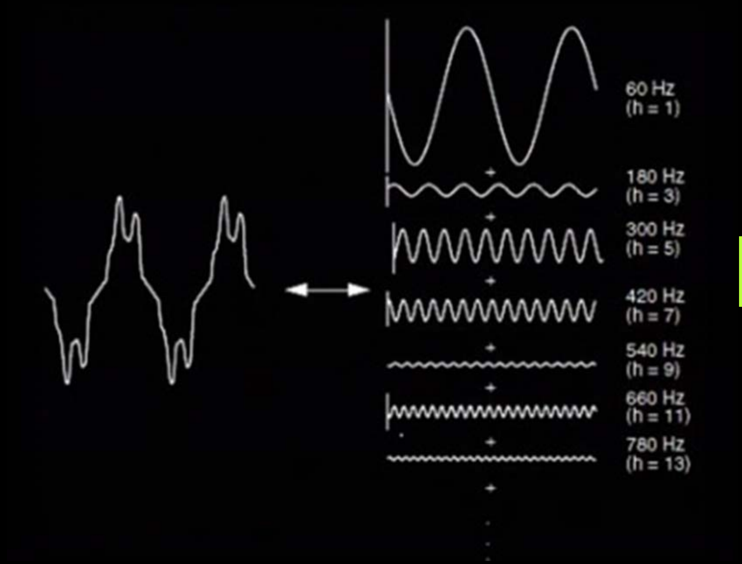


SpaceX Dragon
Capsule Re-entry

3D Sparse Volume data:
3864 x 944 x 464

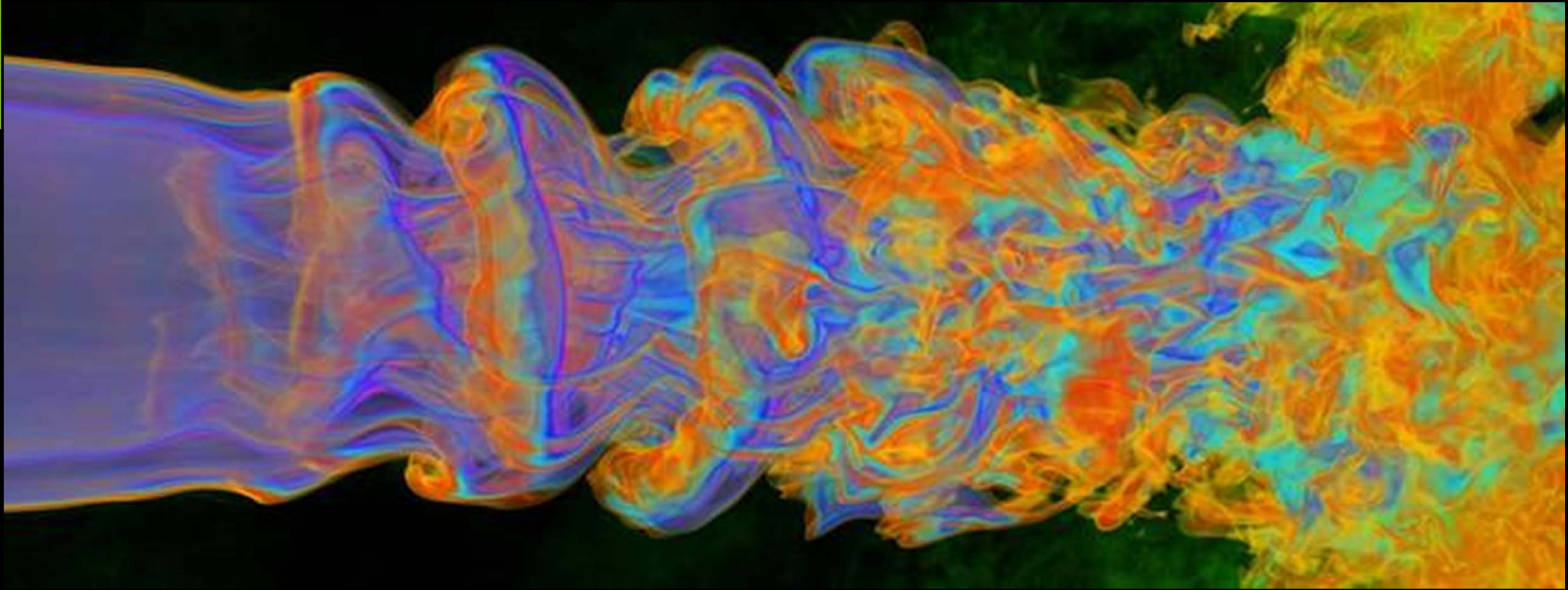
SPACEX

Data Preparation



Wavelet Cloud

Data Visualization



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

NVIDIA INDEX HPC Visualization Using NVIDIA Index

Tom-Michael Thamm, Christopher Lux, Marc Nienhaus

See show floor!

VOLUME VISUALIZATION

Dense Volumes

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0	1	2	2	2	1	0	0
0	0	0	0	0	0	0	0	1	2	3	3	3	2	1	0
0	0	0	0	0	0	0	0	1	2	3	4	3	2	1	0
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0	0	0	0	0	0	0	0	0	1	2	2	2	1	0	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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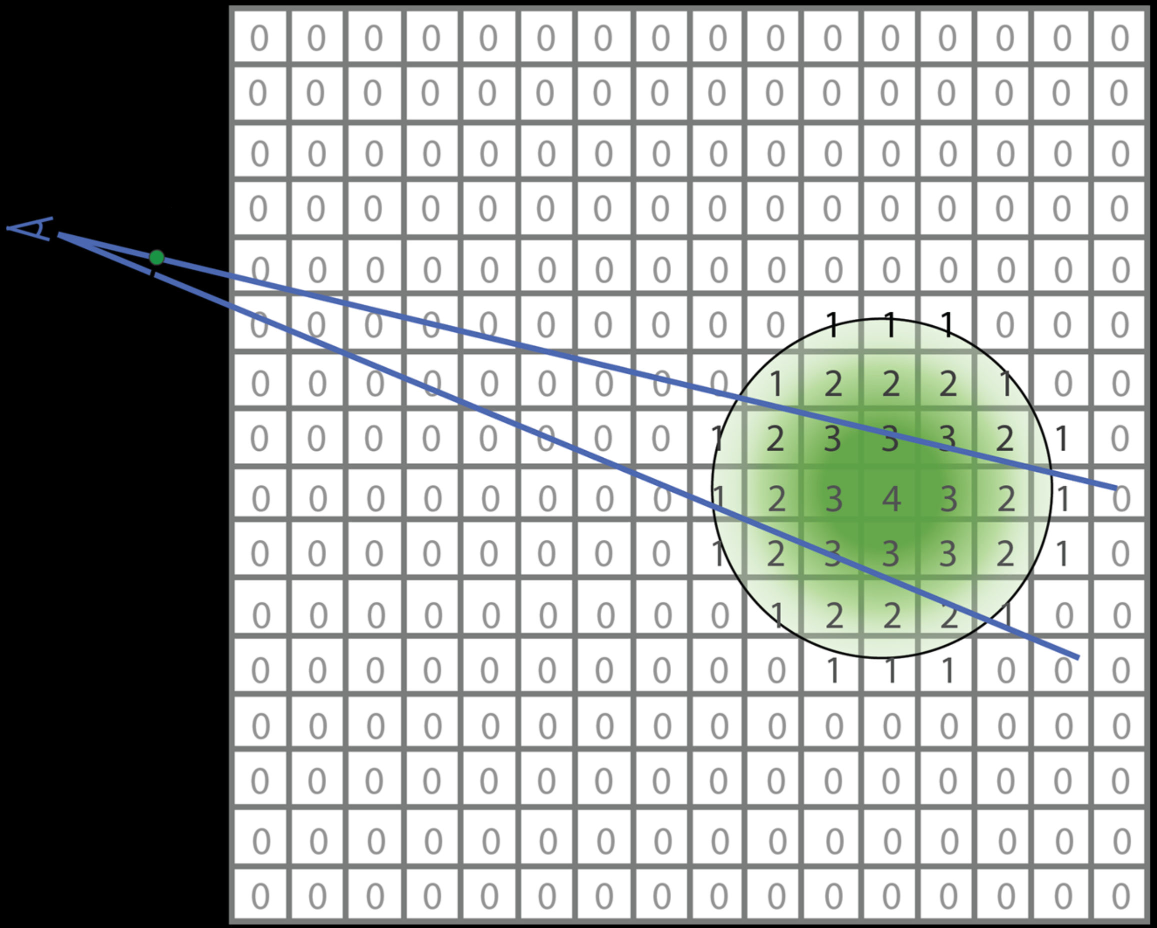
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

16 x 16 =

256 data values

VOLUME VISUALIZATION

Dense Volumes

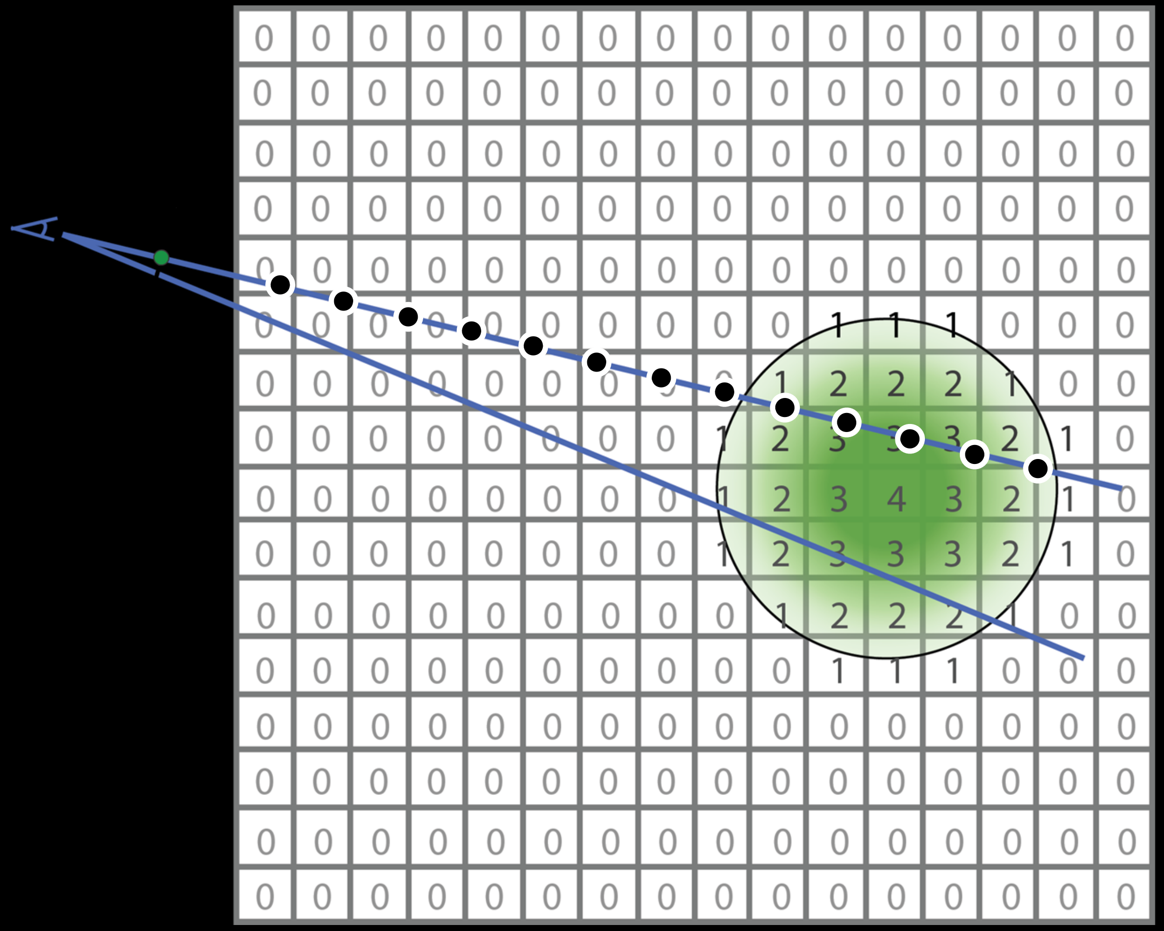


16 x 16 =

256 data values

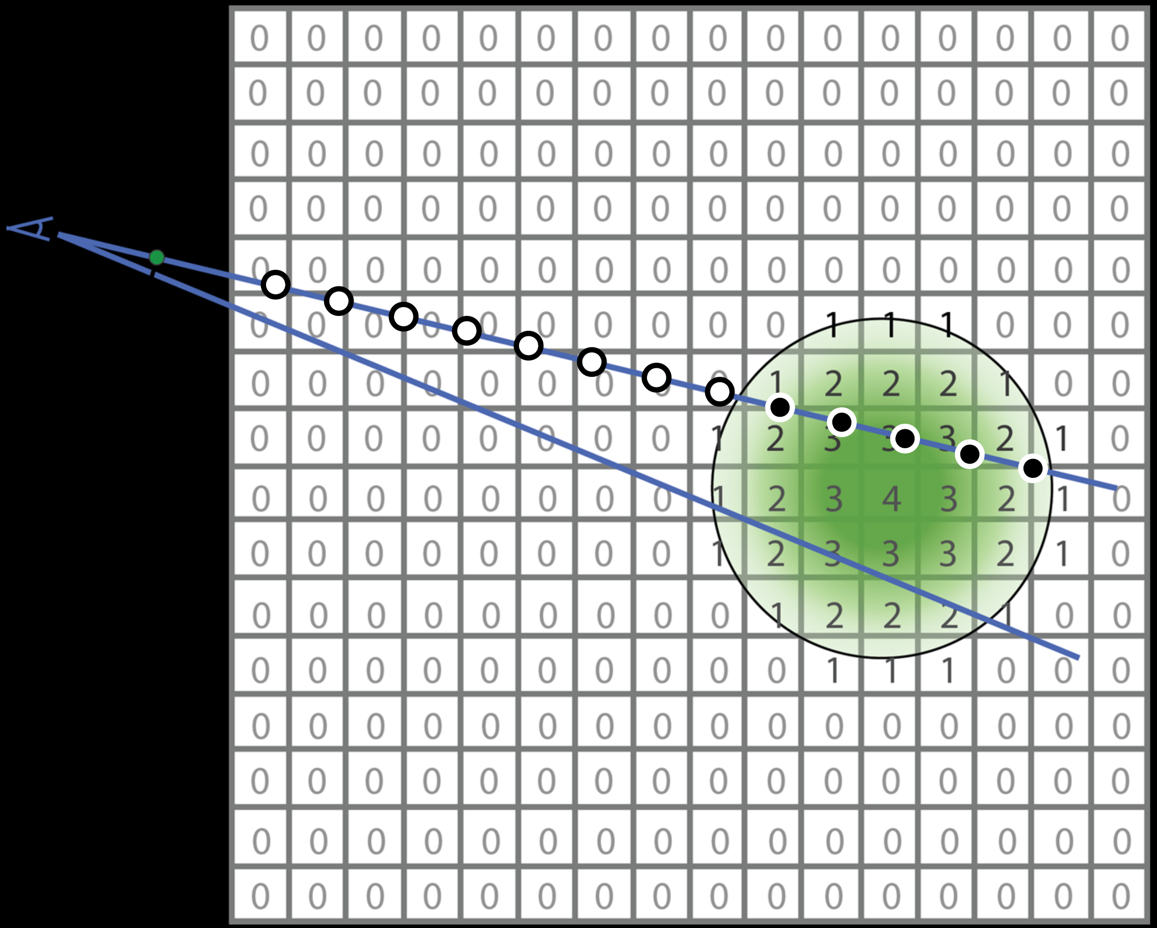
VOLUME VISUALIZATION

Dense Volumes



VOLUME VISUALIZATION

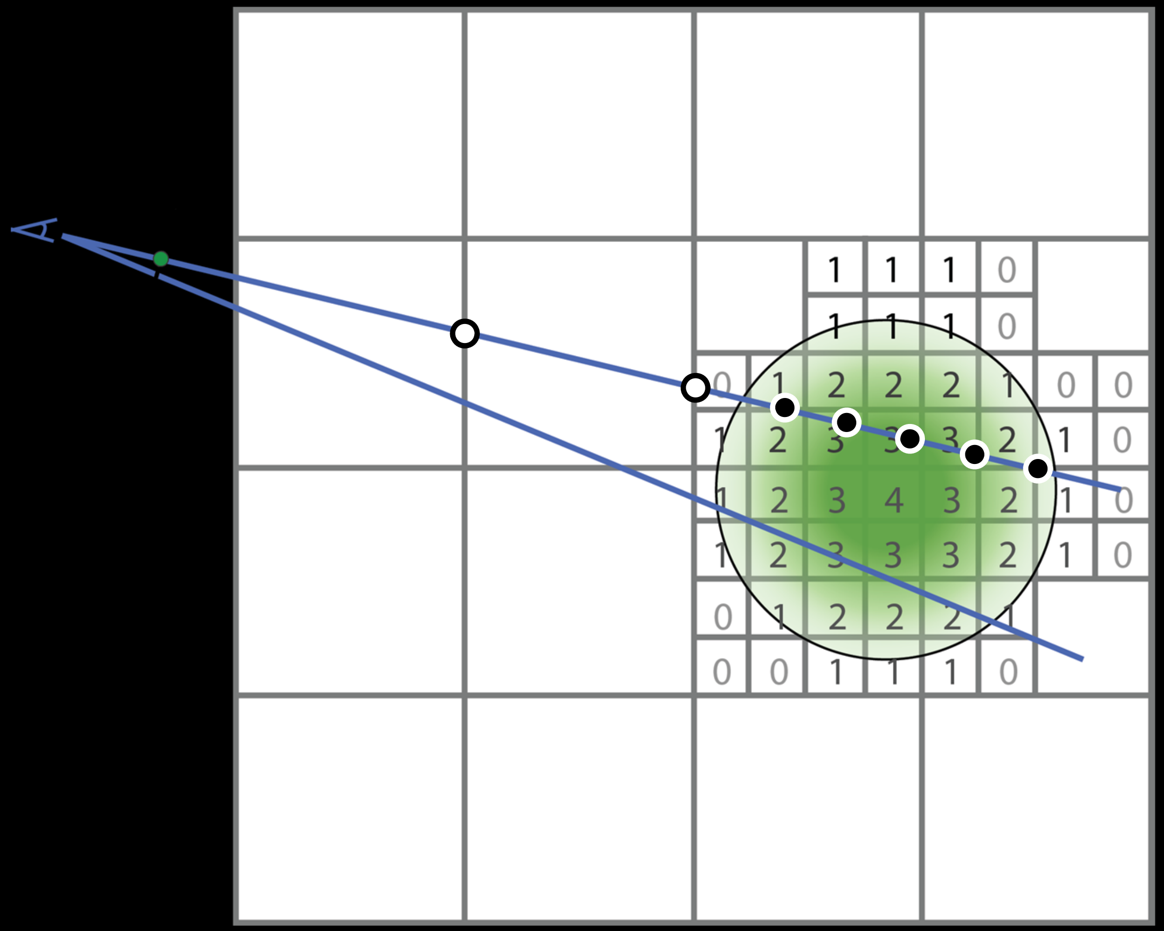
Dense Volumes



- 8 empty steps
- 5 sample steps

VOLUME VISUALIZATION

Sparse Volumes

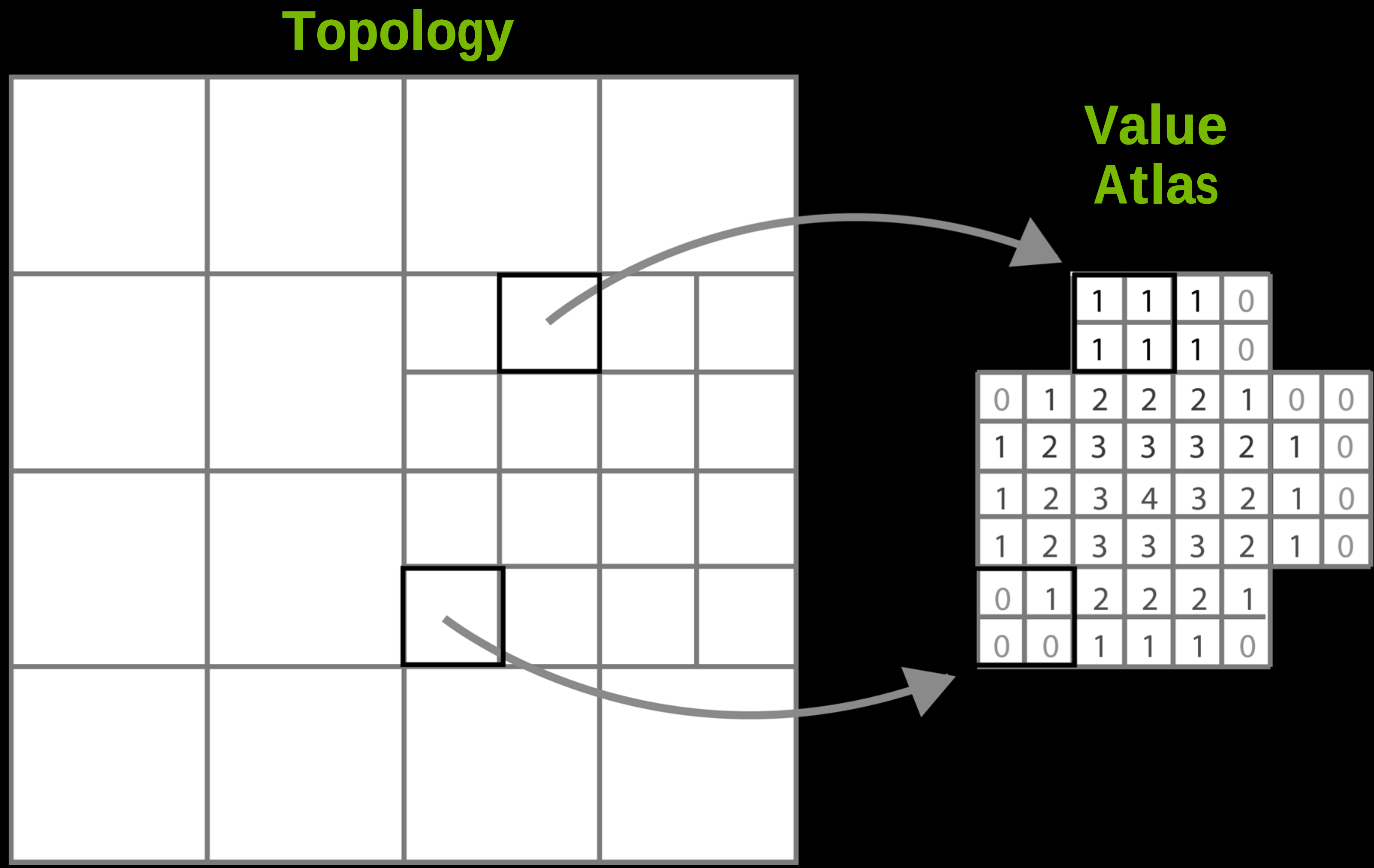


52 data values

(instead of 256!)

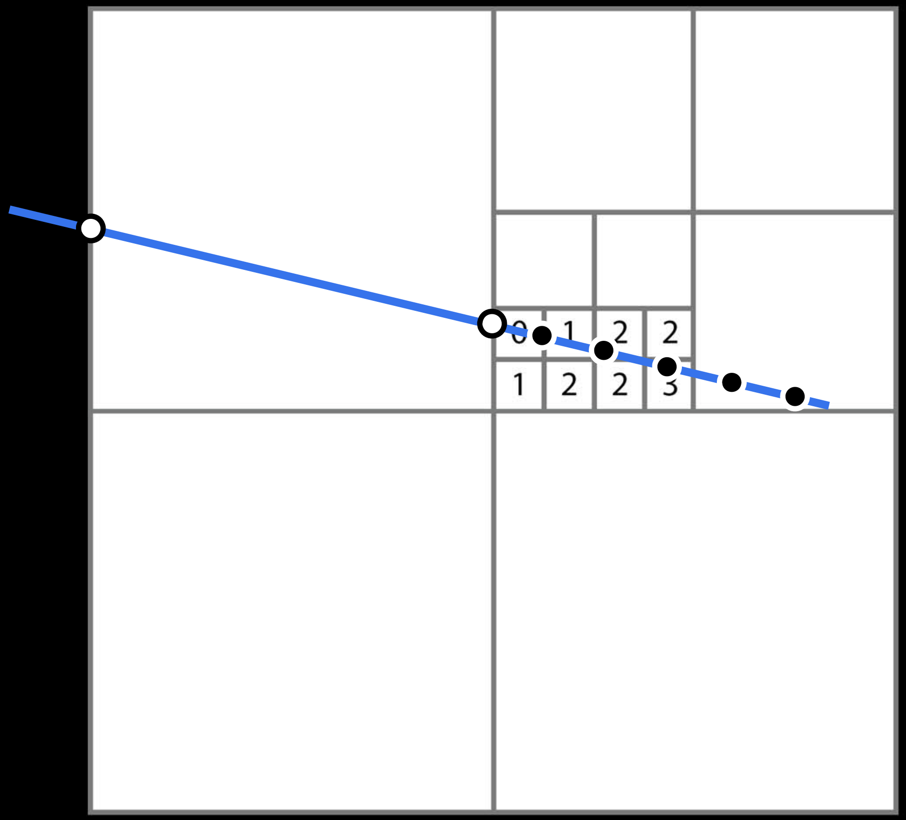
- ● 2 DDA skip steps
- ○ 5 sample steps

VOLUME VISUALIZATION



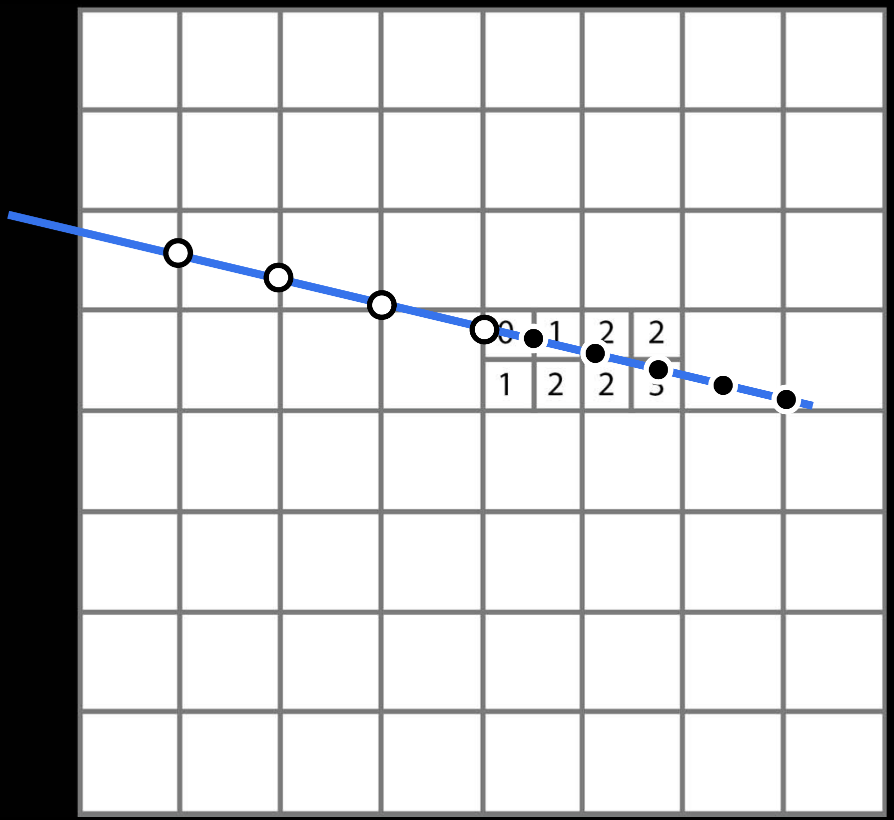
VOLUME VISUALIZATION

Octree Topology



Many levels
Every level divided in half

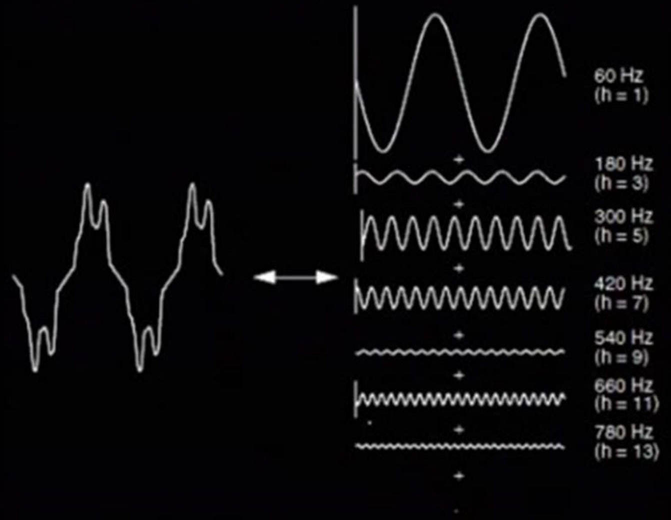
Tilemap Topology



Only two levels
Map has uniform divisions

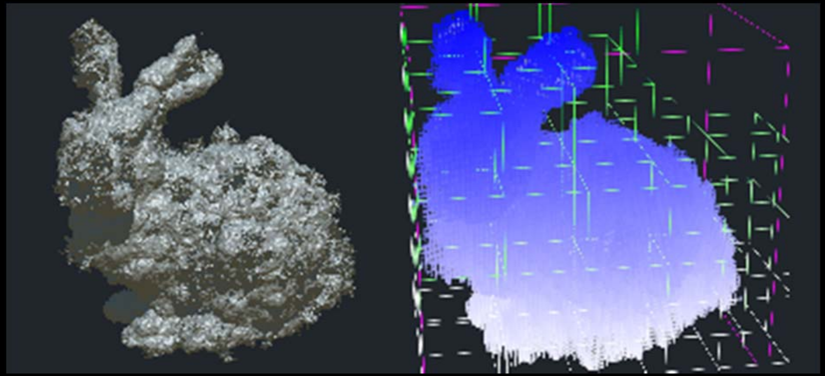
SPACEX

Data Preparation with OpenVDB



Wavelet Cloud

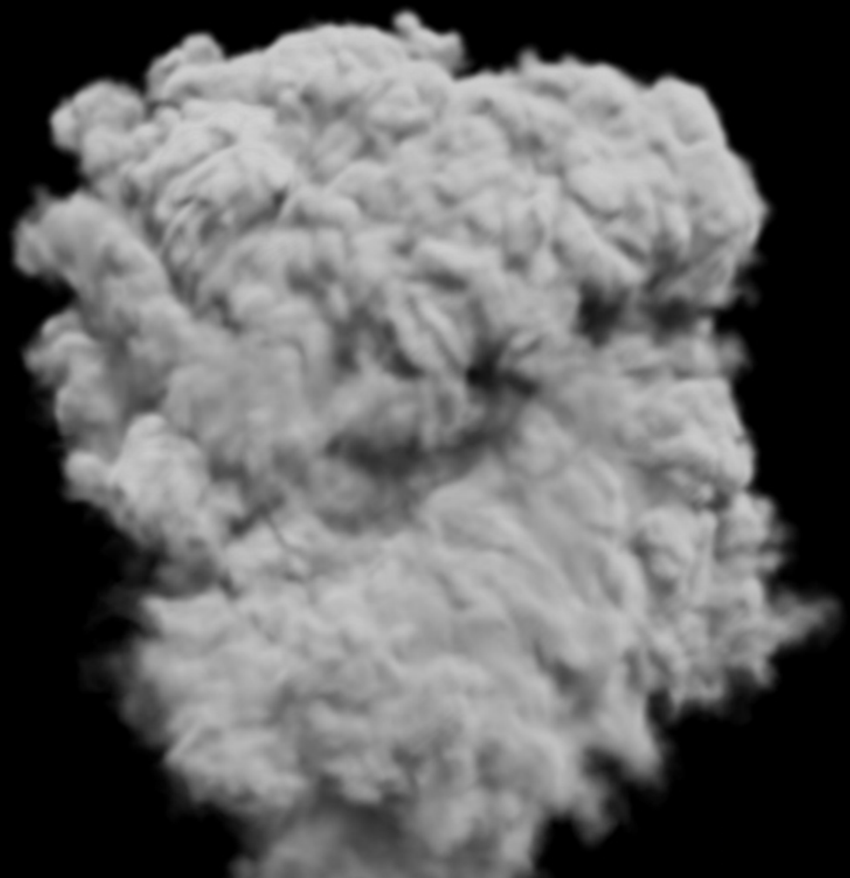
Ideal for GPU Simulation.
Difficult to directly visualize.



OpenVDB Grid

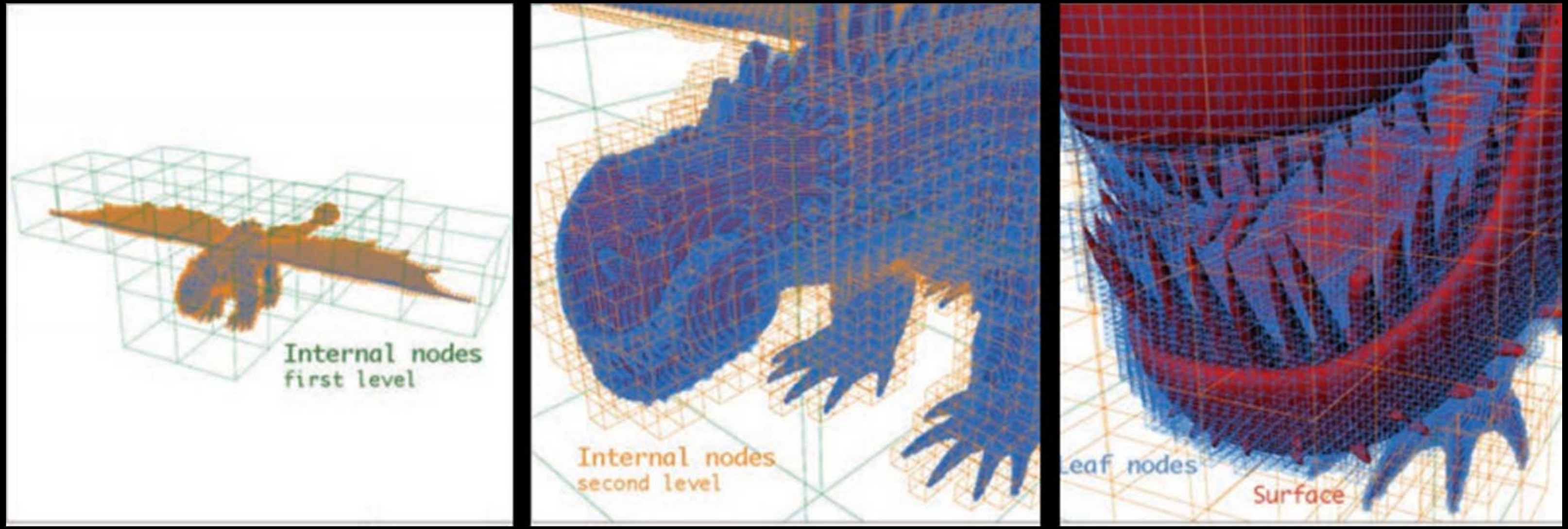
Sparse, Spatial Grid Hierarchy.
Efficent storage and visualization.

MOTION PICTURES: OPENVDB



MOTION PICTURES: OPENVDB

Sparse Hierarchy of Grids



Novel topology for *very large volumes.*
Multi-core CPU Design

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

OPENVDB

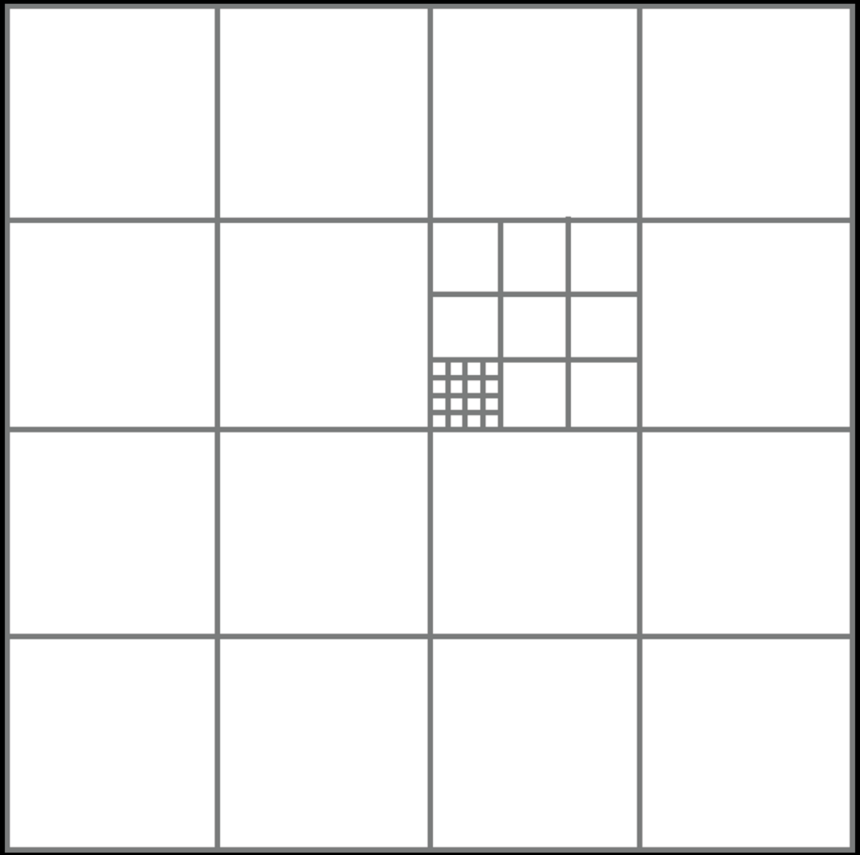
VDB Topology

Many levels

Each level is a grid

Each level has its
own resolution

e.g. top = 4x4
mid = 3x3
brick = 4x4



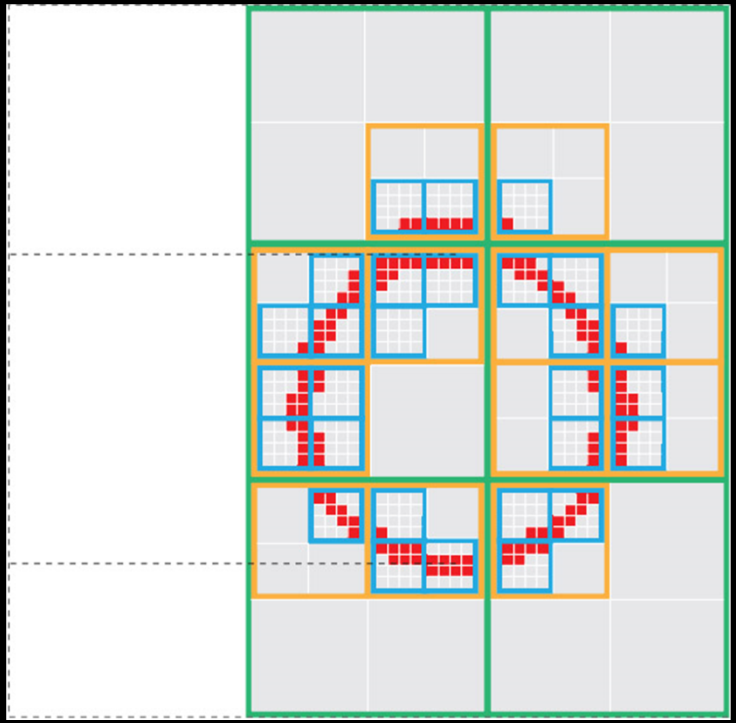
Key features:

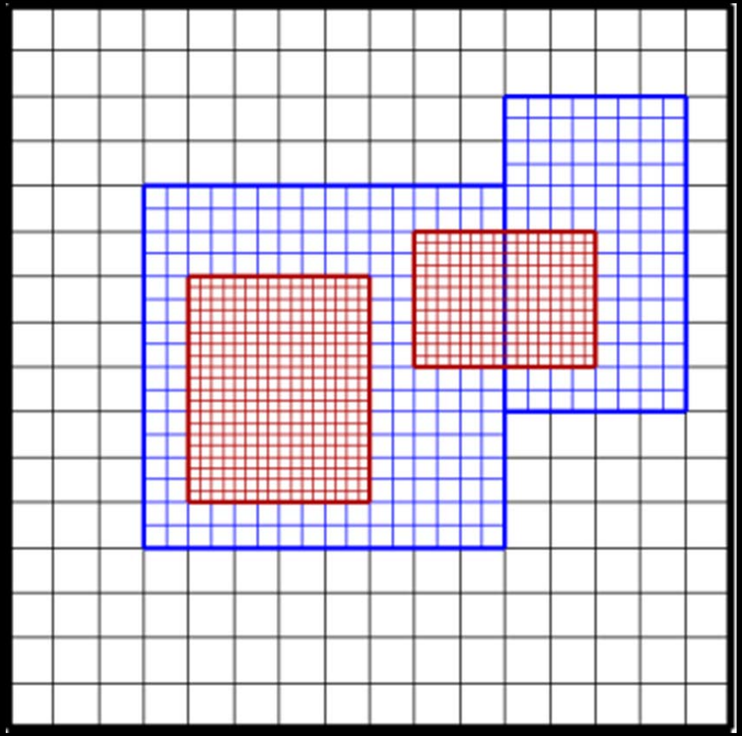
Can store
very large volumes
with only a *few* **levels.**

Efficient to traverse,
since every level is a grid.

OPENVDB VS AMR

Sparse Hierarchy of Voxel Grids





OpenVDB:
1) Children are strictly contained
2) Spatial extent is a voxel of parent
3) All siblings have same resolution

Adaptive Mesh Refinement (AMR):
1) Children are strictly contained
2) Spatial extent is free in parent
3) Siblings can have different res

SUMMARY OF GOALS

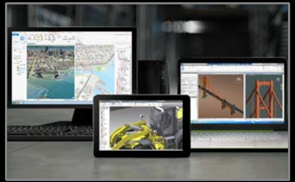
1. Load and Visualize Sparse Grids
2. Using the VDB Data Structure
3. ..with.. Efficient Rendering on GPU
4. ..and.. *High quality Raytracing*

NVIDIA® DESIGNWORKS™

DISPLAY

Multi-Display

GRID SDK



Virtual Reality

LIVE VIDEO

GPUDirect for Video

Video Codec SDK

VIRTUAL REALITY

VR Works

RENDERING

Iray SDK

OptiX

GVDB

VXGI

MATERIALS

MDL SDK

vMaterials

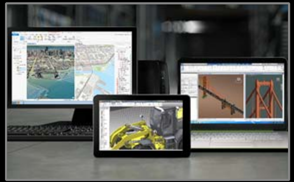
NVIDIA DesignWorks™ - Advanced technologies for design applications

https://developer.nvidia.com/designworks

NVIDIA® DESIGNWORKS™

Multi-Display

GRID SDK



Virtual Reality

DISPLAY

GPUDirect for Video

Video Codec SDK

LIVE VIDEO

VR Works

VIRTUAL REALITY

Iray SDK

OptiX

* NEW *

GVDB

VXGI

RENDERING

MDL SDK

vMaterials

MATERIALS

NVIDIA DesignWorks™ - Advanced technologies for design applications

https://developer.nvidia.com/designworks

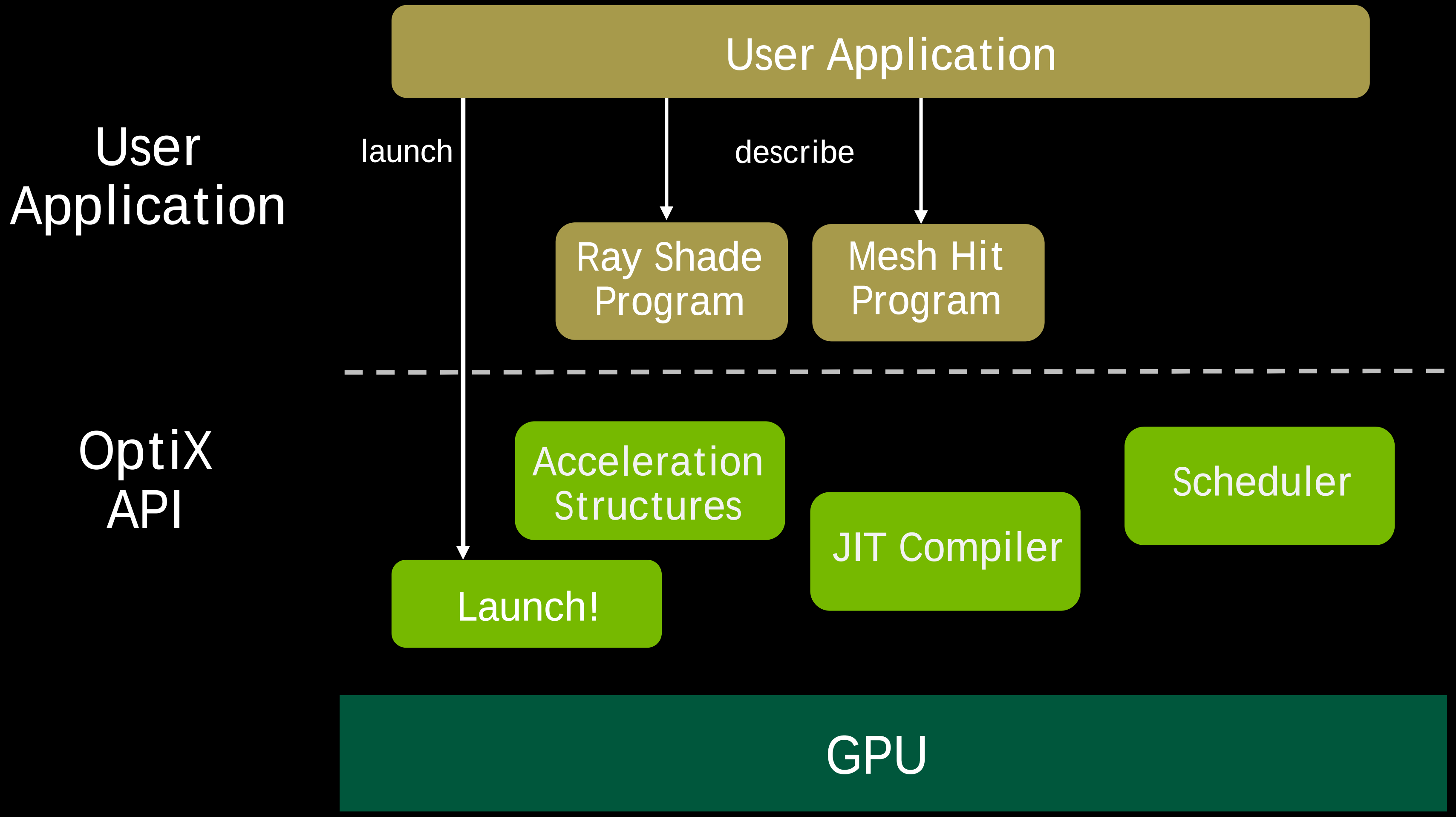
GPU TECHNOLOGY CONFERENCE

NVIDIA® OPTIX™

OptiX: A General Purpose Ray Tracing Engine

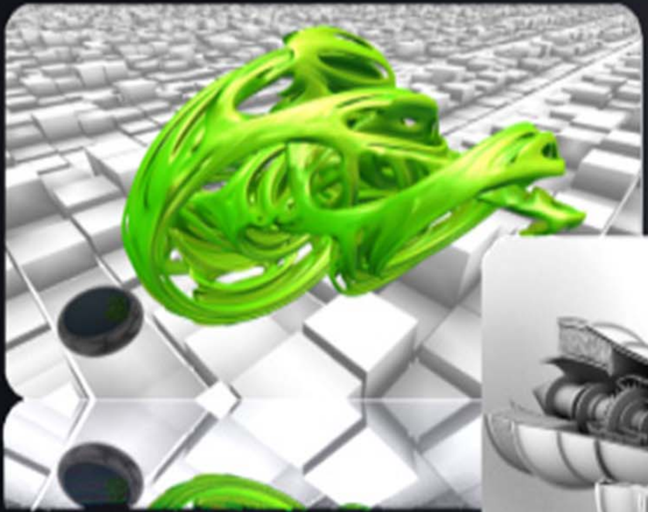
OptiX: A General Purpose Ray Tracing Engine, Steven Parker, NVIDIA
ACM Transactions on Graphics, Vol. 29, No. 4, July 2010

GTC 2016 Talks: S6643, S6244
S6258, S6844, S6261, S6320

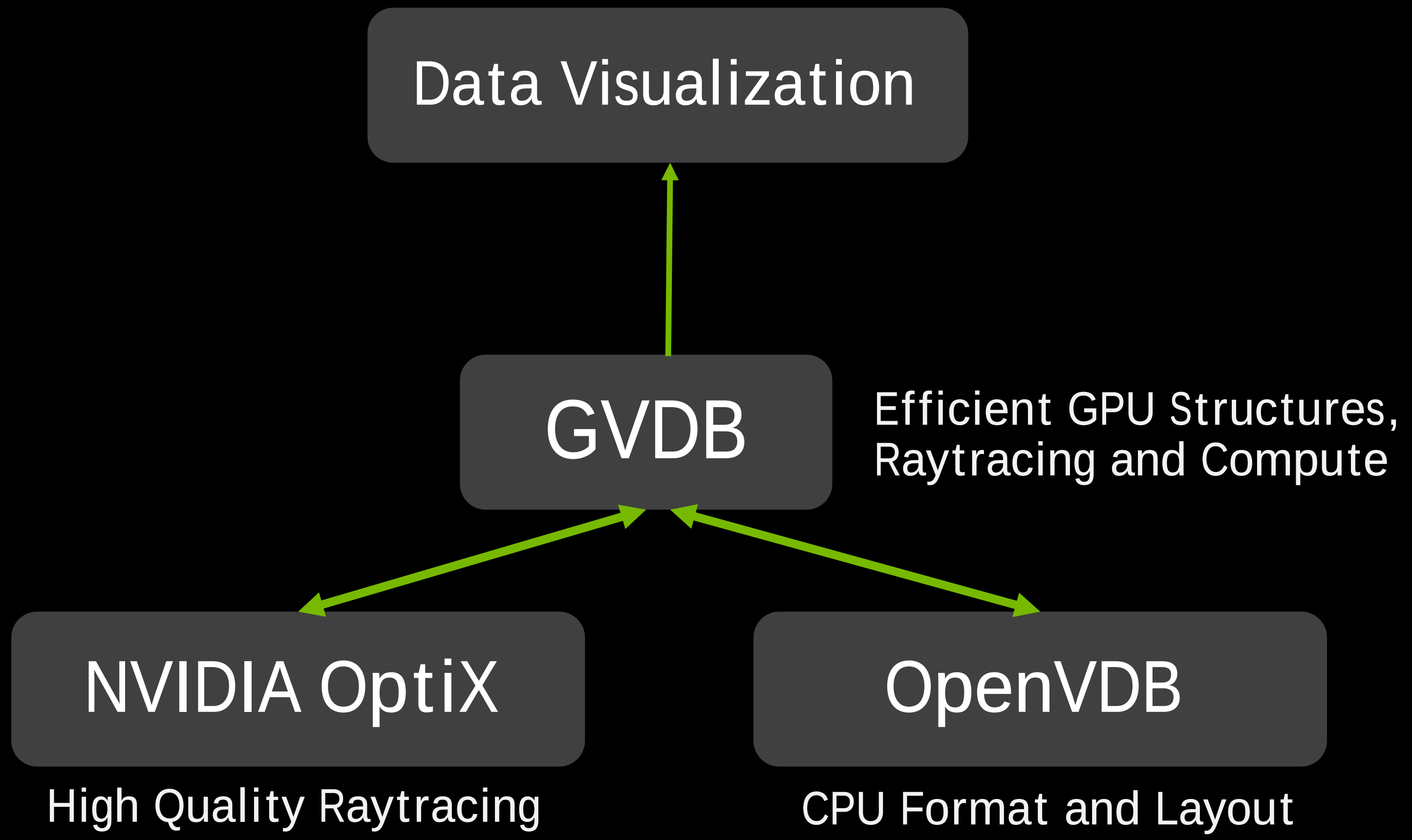

NVIDIA OPTIX™
User Application
User
Application
launch
describe
Ray Shade
Program
Mesh Hit
Program
OptiX
API
Acceleration
Structures
JIT Compiler
Scheduler
Launch!
GPU

OptiX SDK

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



NVIDIA GVDB SPARSE VOLUMES



NVIDIA GVDB SPARSE VOLUMES

What is GVDB?

VDB Sparse Voxel Structures entirely on GPU

Efficient Direct Raytracing

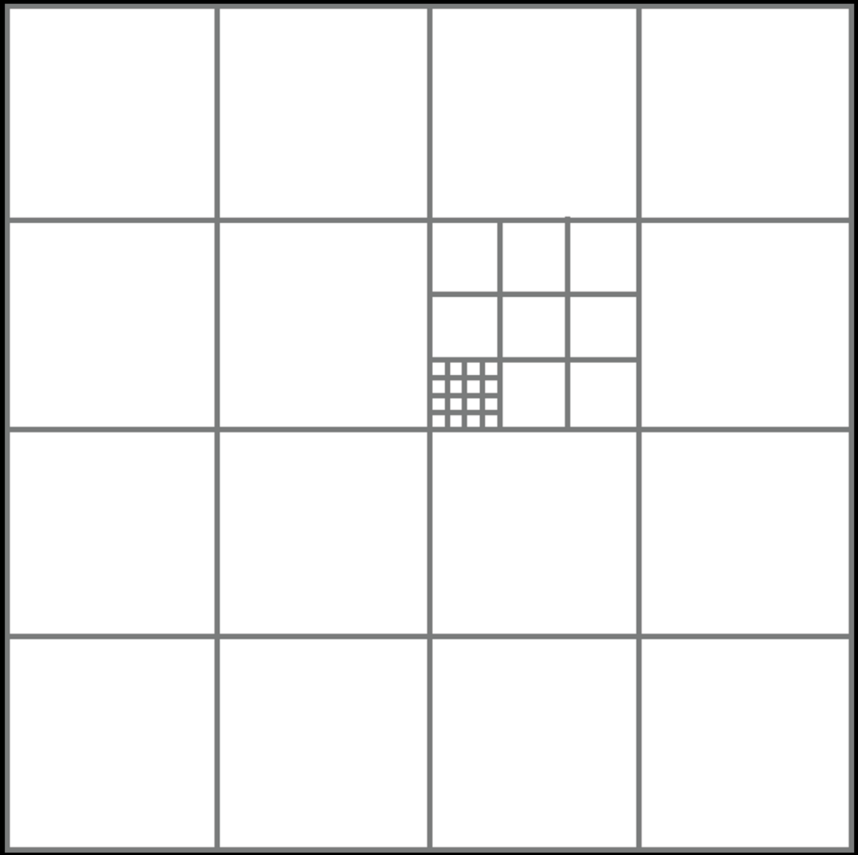
Compatible with OpenVDB files and layout

Integrated with NVIDIA OptiX

Compute Operations on Sparse Volumes

NVIDIA GVDB SPARSE VOLUMES

VDB Topology



Additional features:

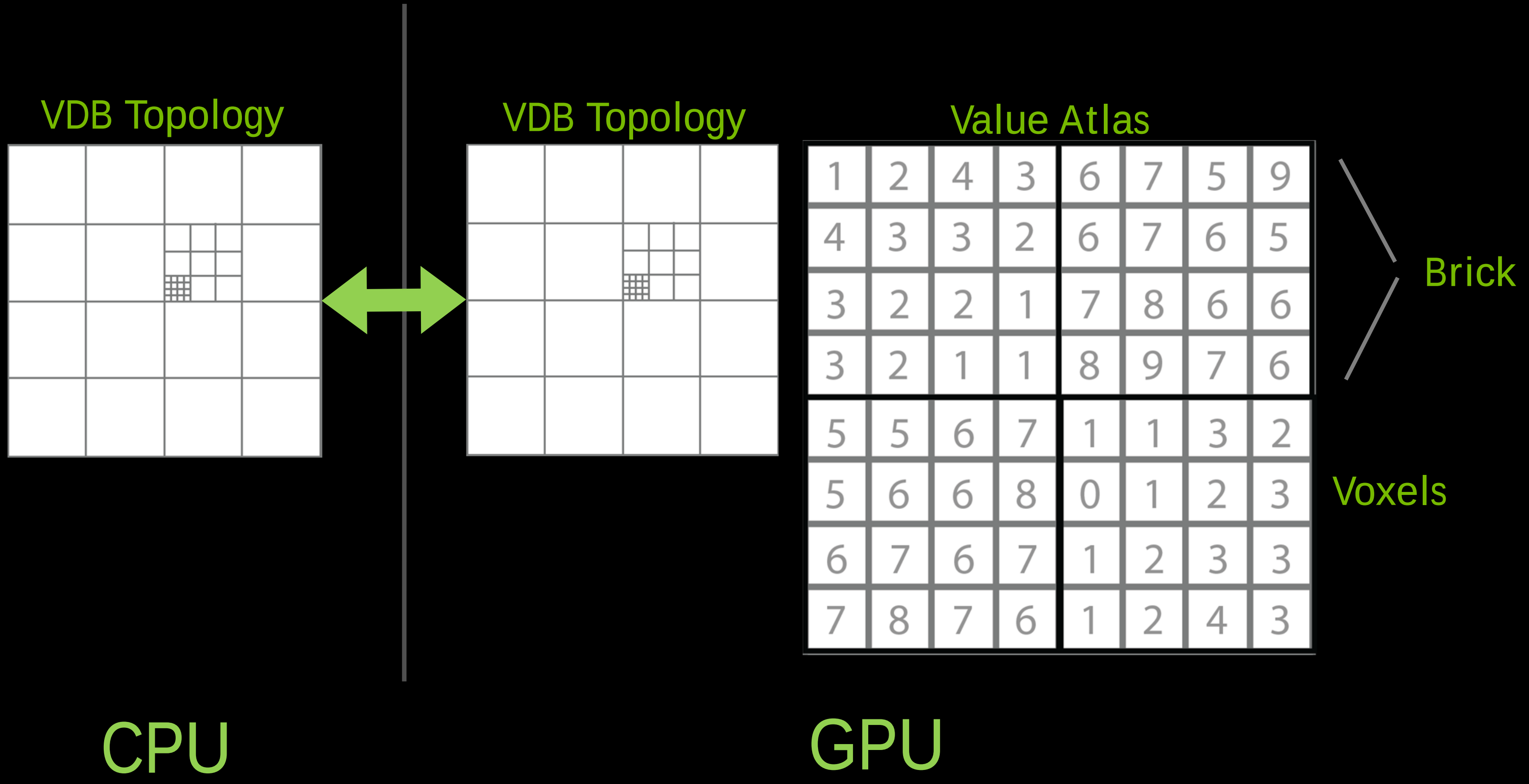
Run-time tree configuration

Dynamic topology

Efficient construction

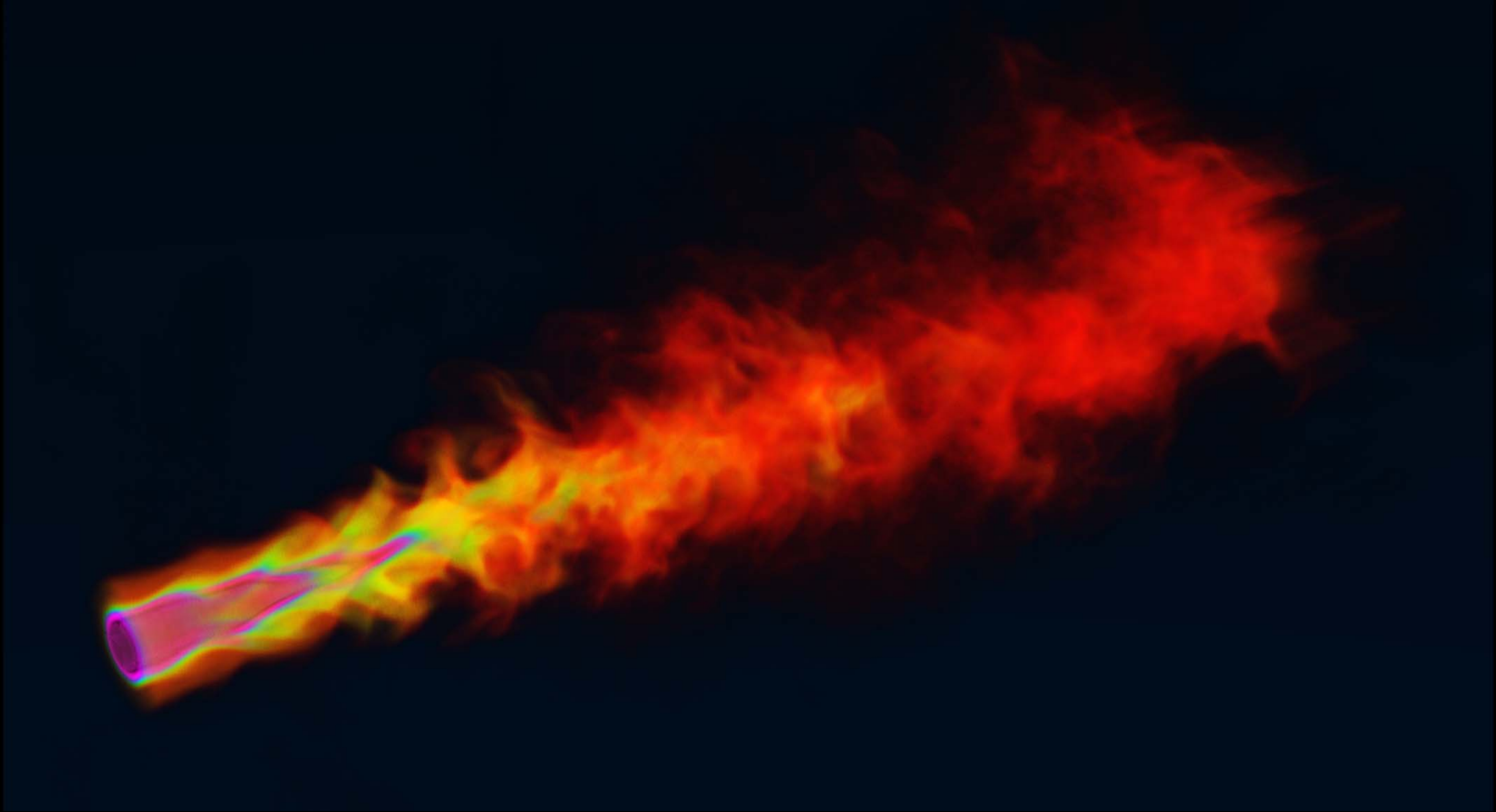
Same topology as OpenVDB

NVIDIA GVDB SPARSE VOLUMES

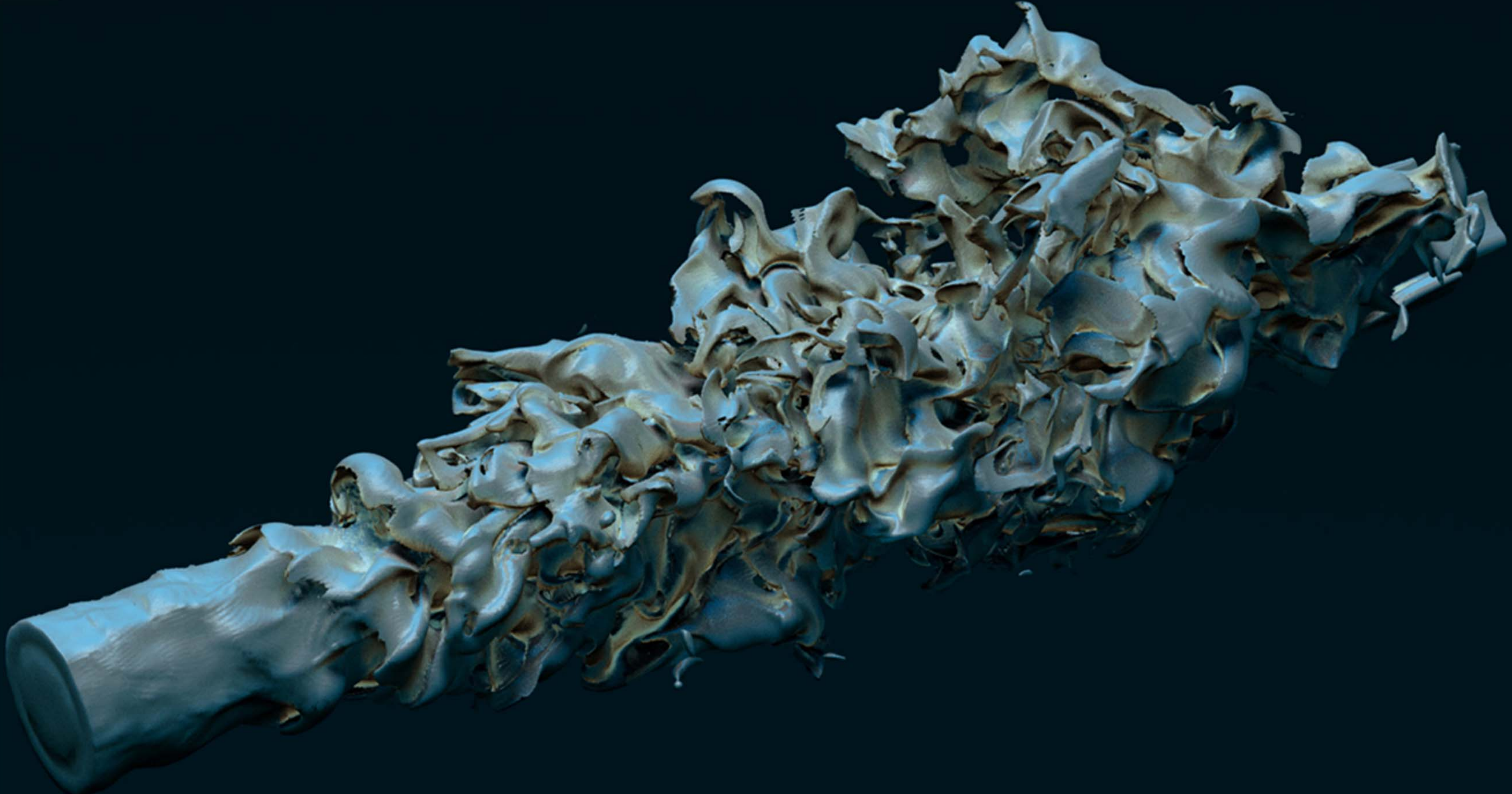


RESULTS

624 x 304 x 304 (133 MB/frame)



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



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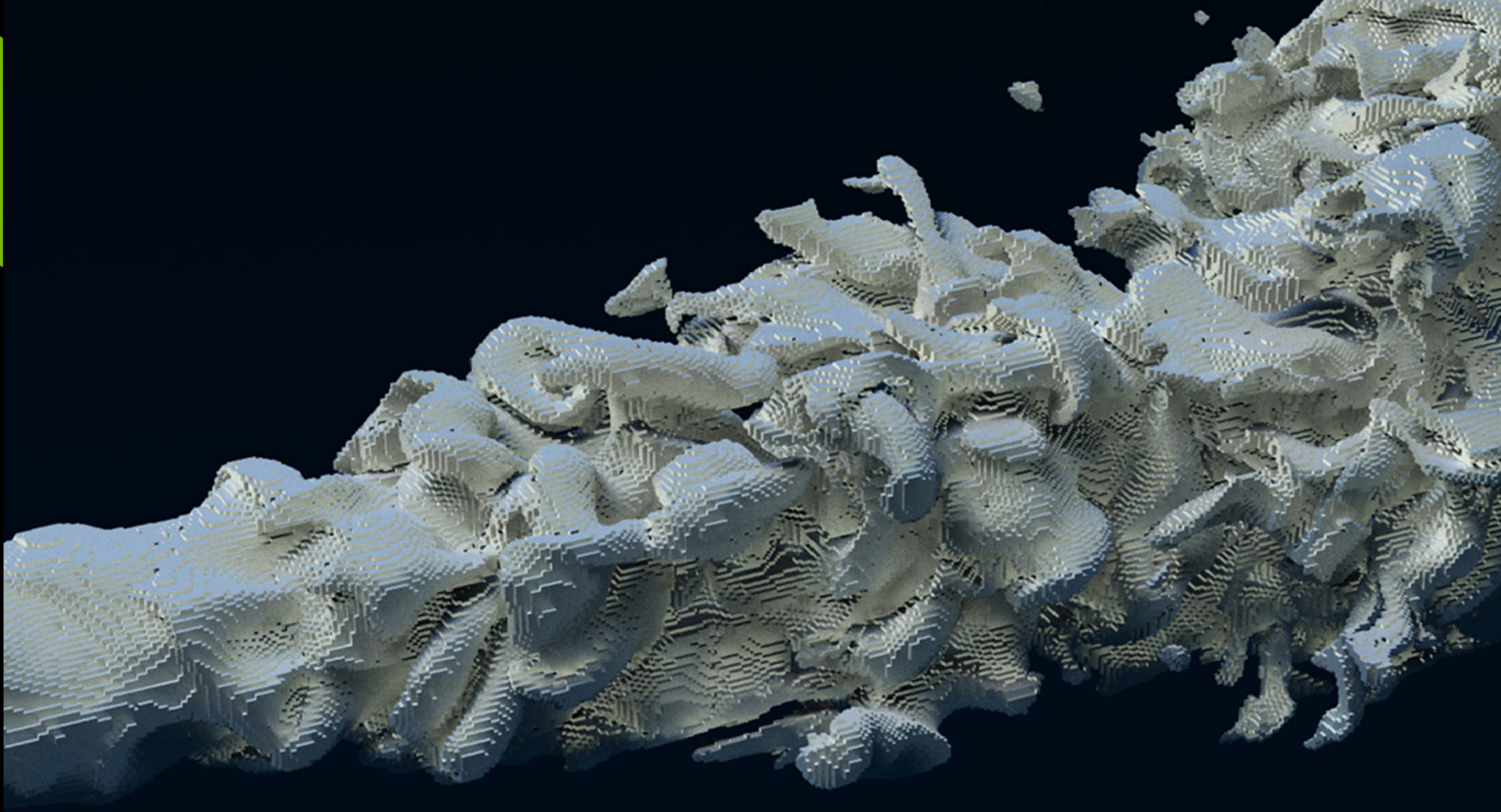

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GVDB SPARSE VOLUMES

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

RESULTS

Scalability Testing

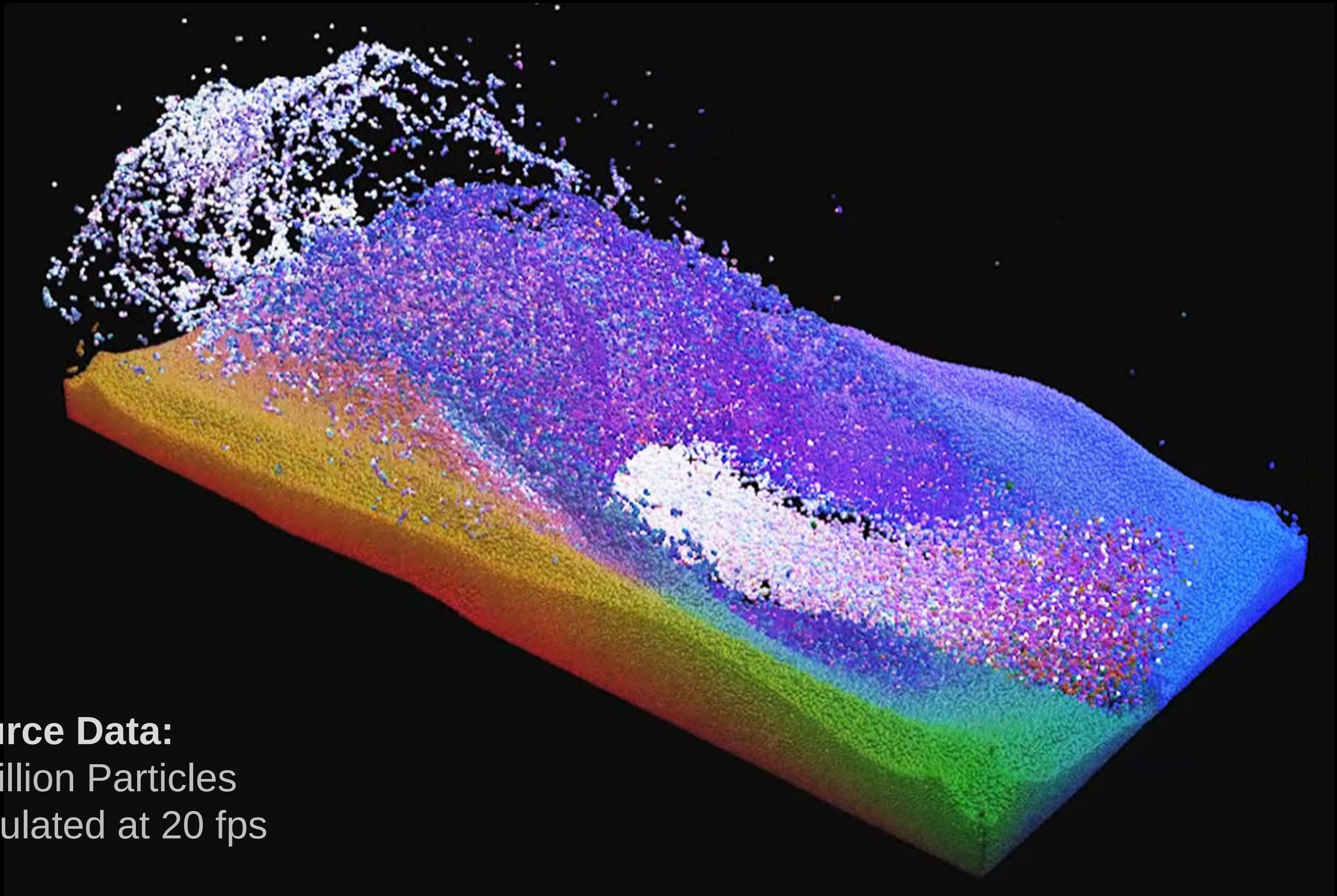
Fluid simulations from Smooth Particle Hydrodynamics

1,000,000 Particle simulation on GPU using Fluids v.3, http://fluids3.com

Generated volumes at multiple resolutions by resampling velocity field

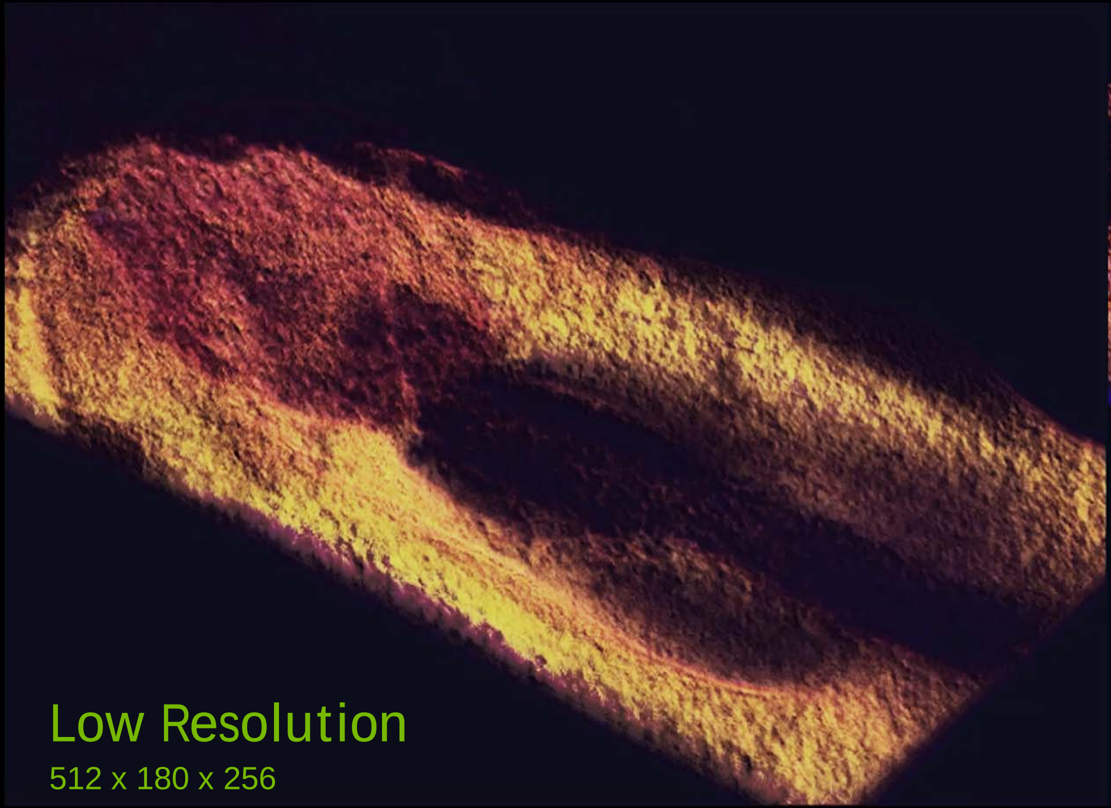
Low-res:	512 x 180 x 256,	50 MB/frame,	60 GB total
Med-res:	1024 x 360 x 512,	338 MB/frame,	408 GB total
High-res:	2048 x 720 x 1024,	2.4 GB/frame,	3 TB total

RESULTS



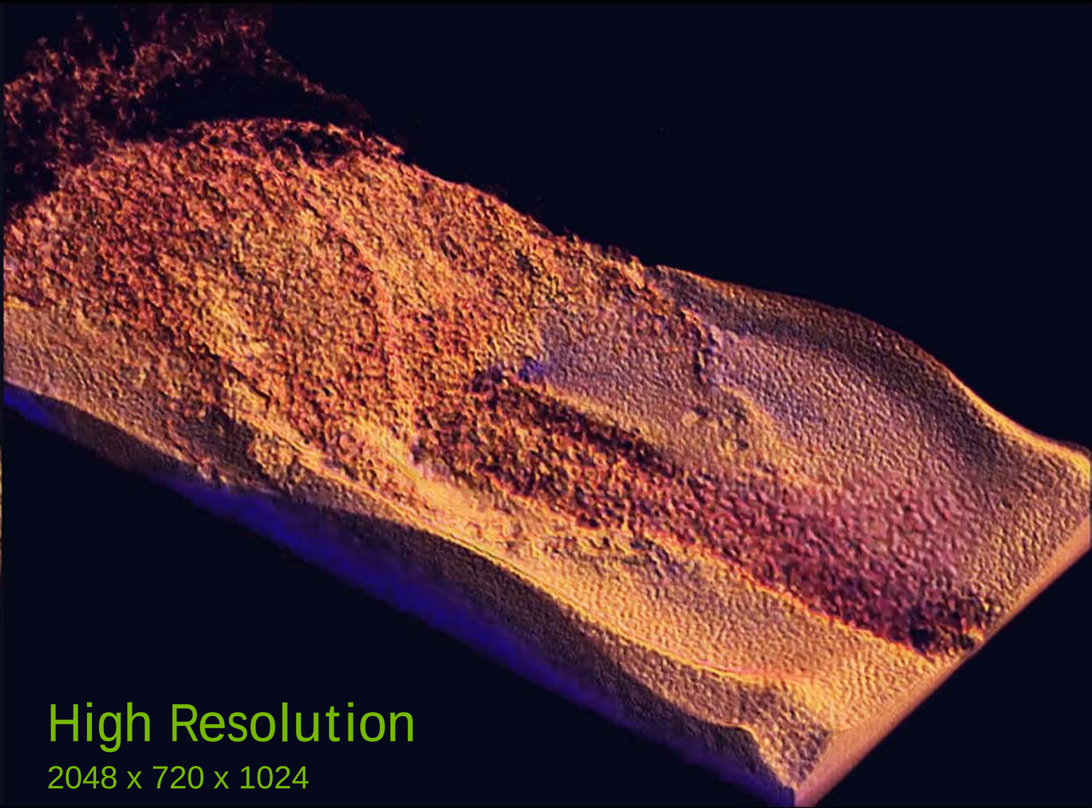
Source Data:
1 million Particles
Simulated at 20 fps

RESULTS



Low Resolution

512 x 180 x 256



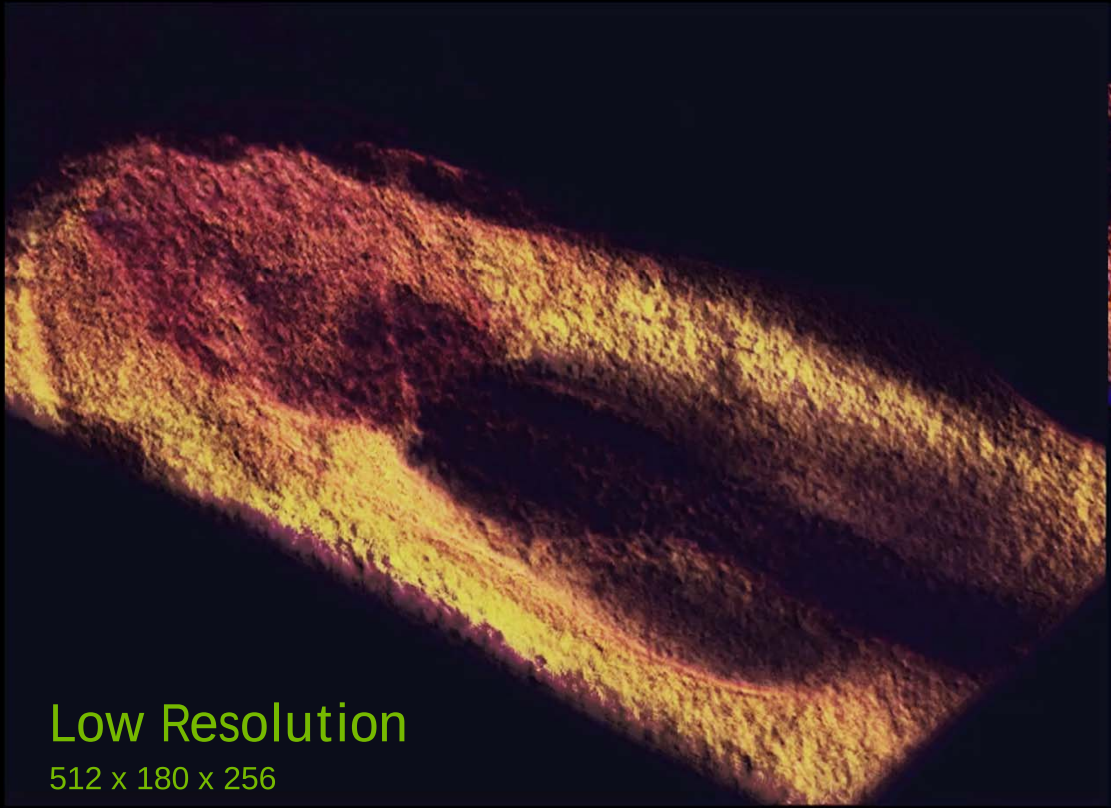
High Resolution

2048 x 720 x 1024

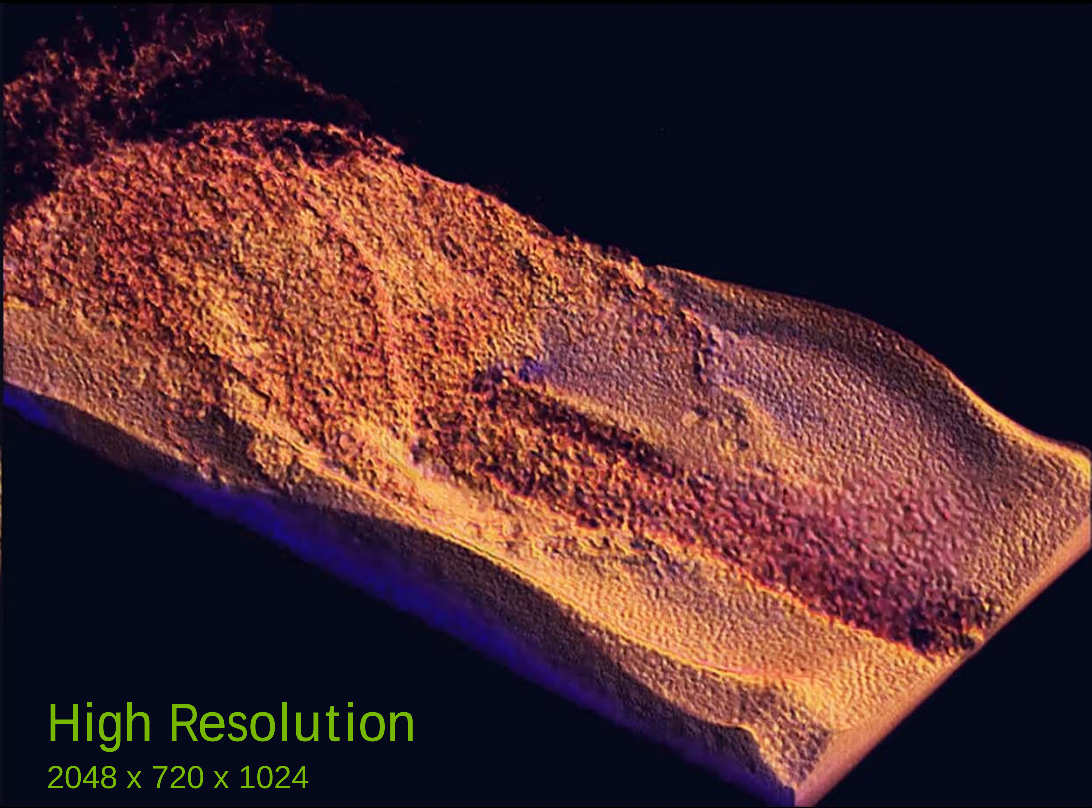
# of Leaves:	12,131
File size:	50 MB/frame
GPU Resampling:	16 seconds/frame
Load Atlas:	450 msec/frame
Raytracing:	27 msec/frame
	38 fps

# of Leaves:	616,444
File size:	2400 MB/frame
GPU Resampling:	804 seconds/frame
Load Atlas:	5420 msec/frame
Raytracing:	64 msec/frame
	15 fps

RESULTS



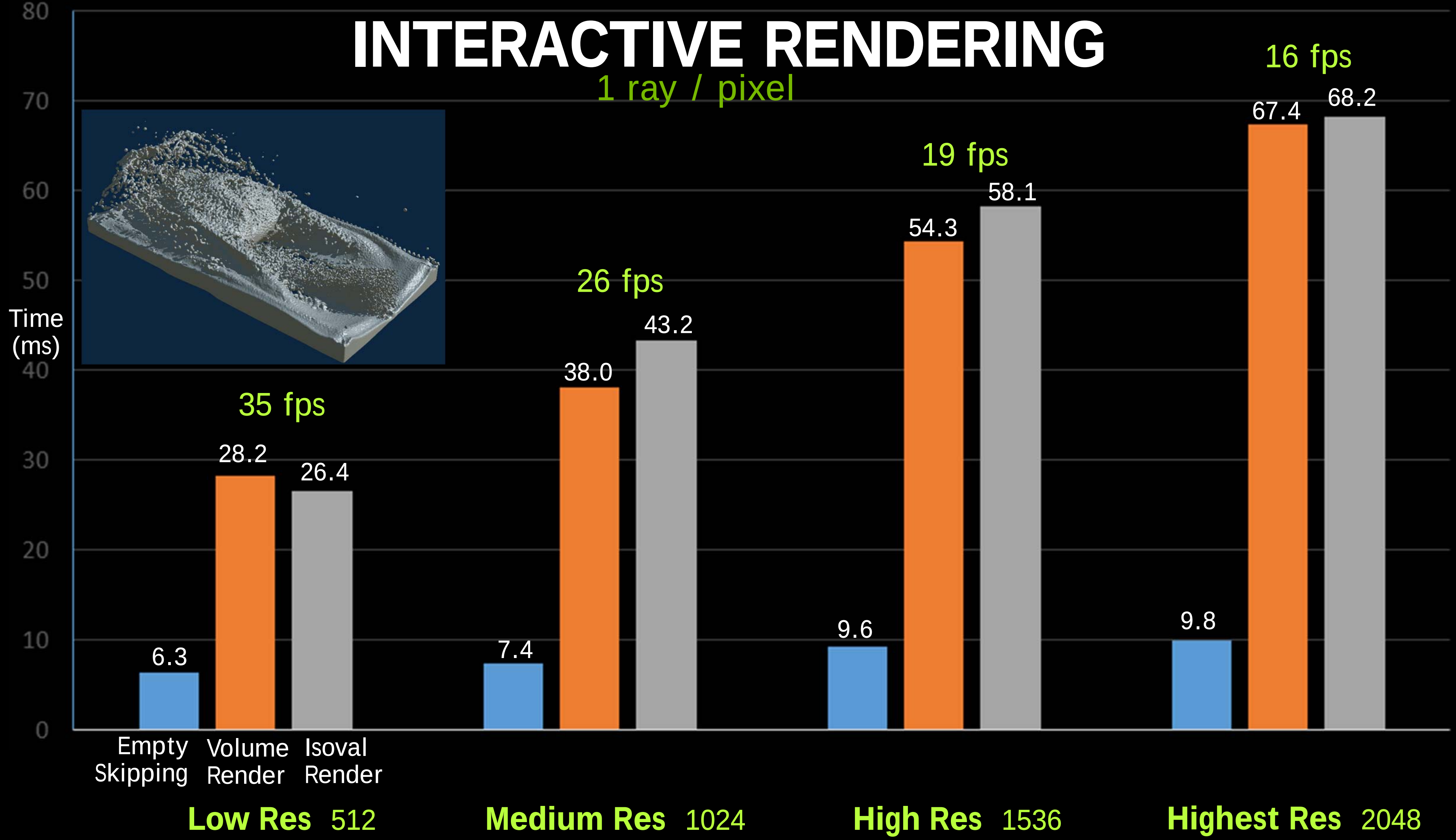
Low Resolution
512 x 180 x 256

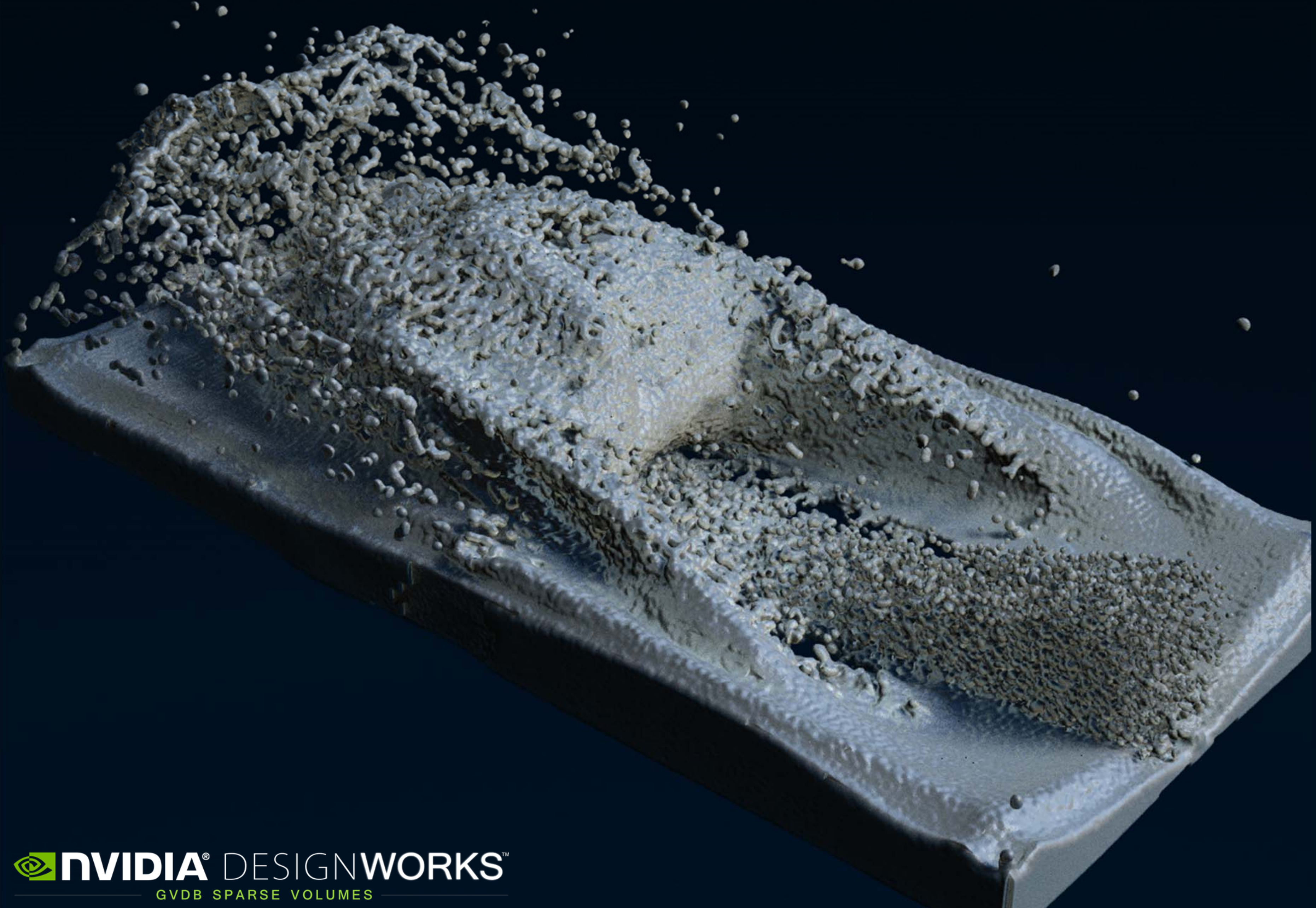


High Resolution
2048 x 720 x 1024

	Low Resolution		High Resolution
# of Leaves:	12,131	48x more data →	616,444
File size:	50 MB/frame		2400 MB/frame
GPU Resampling:	16 seconds/frame		804 seconds/frame
Load Atlas:	450 msec/frame	2x time →	5420 msec/frame
Raytracing:	27 msec/frame		64 msec/frame
	38 fps		*15 fps*

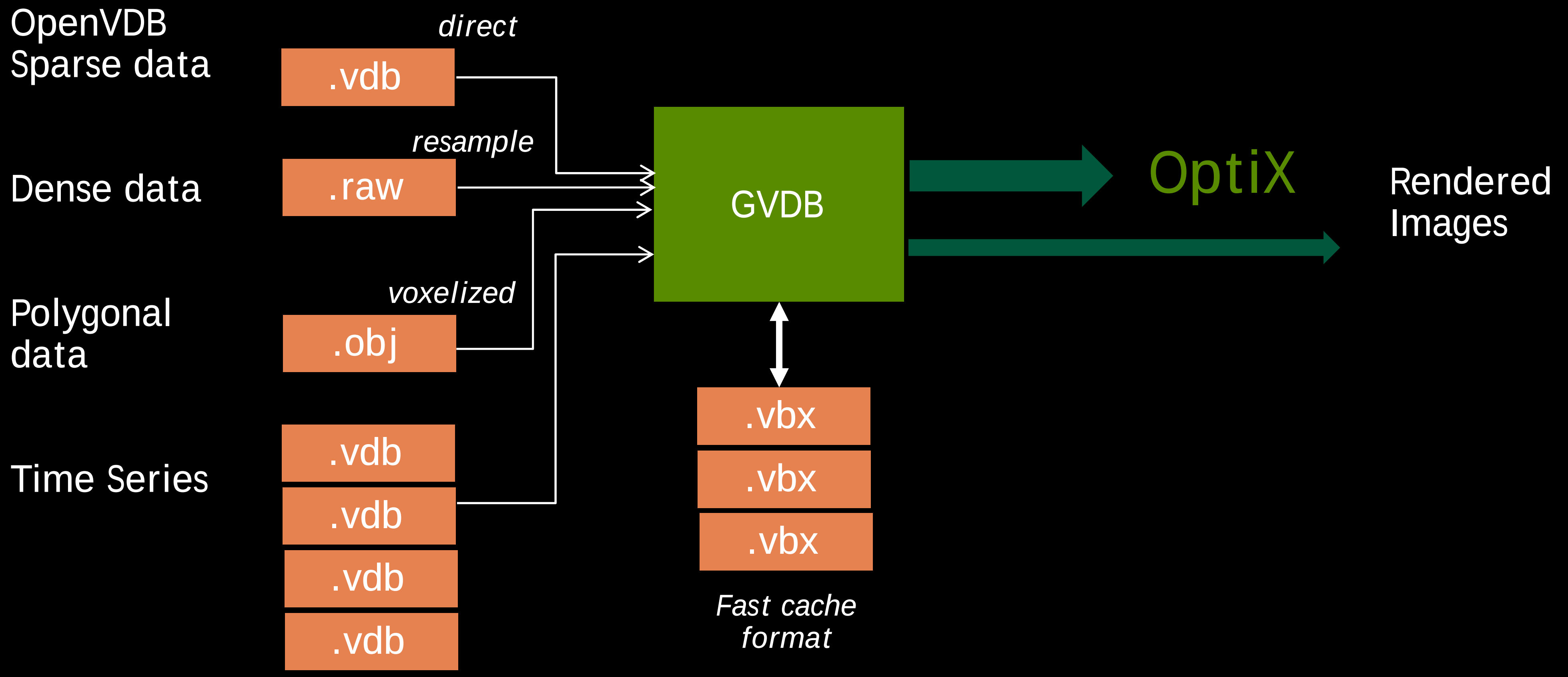
INTERACTIVE RENDERING





NVIDIA GVDB SPARSE VOLUMES

Data Management



NVIDIA GVDB SPARSE VOLUMES

Data Example: Simulate, Process and Raytrace of 1200 frames

Simulate *Processing* *Render*

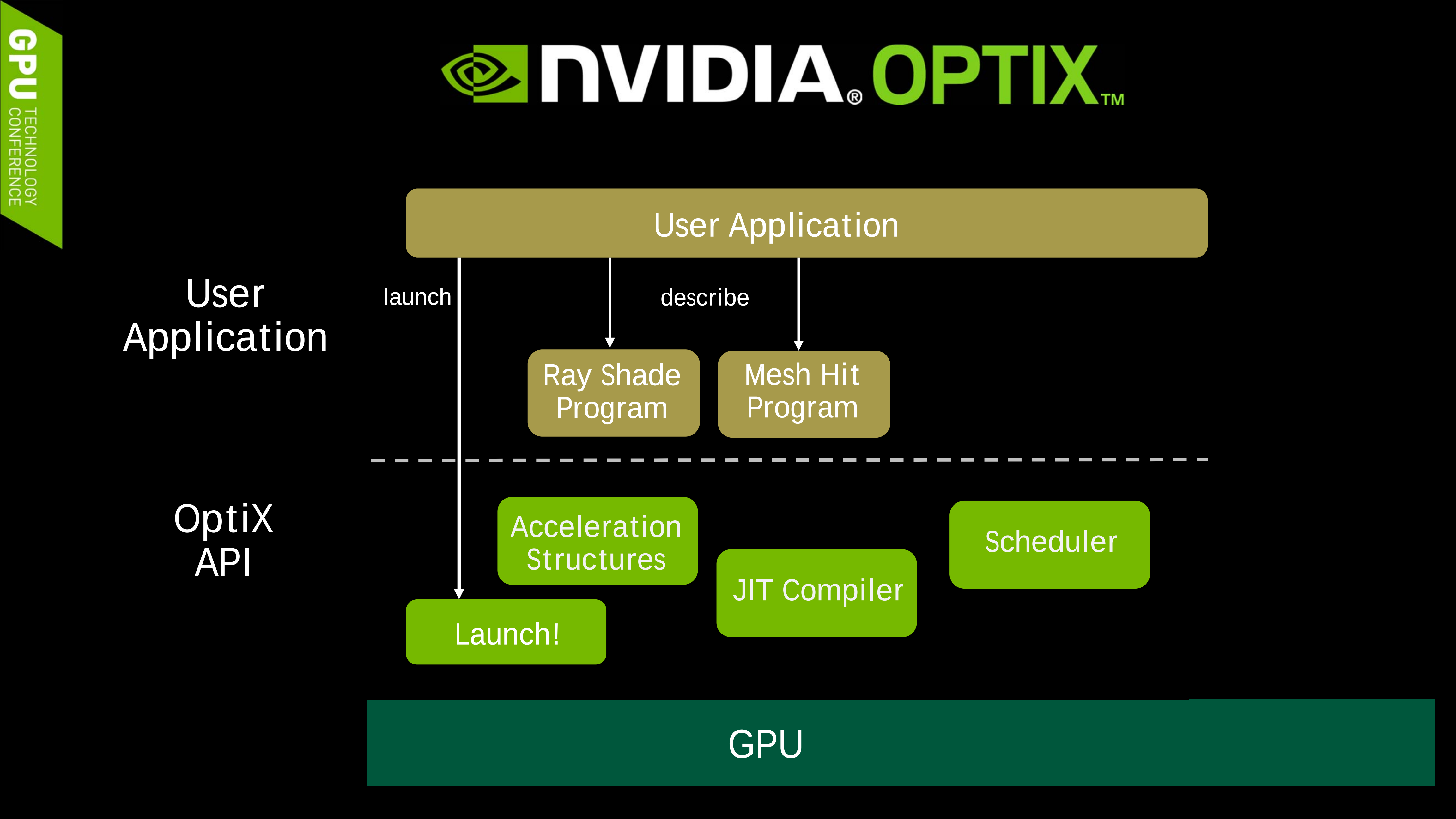
4 seconds/ frame

Total:	1 min	6 hours	1 hours	9 min	46 min
	SPH Simulation	Resample Points to 1024^3 Grid	Write VBX	Read VBX	Raytrace
	On GPU /w Fluids v.3	*On GPU Sparse resample*	*Disk total 530 GB*		

Rendering:

1200 frames in <1 hour with shadows and scattering

192 rays / pixel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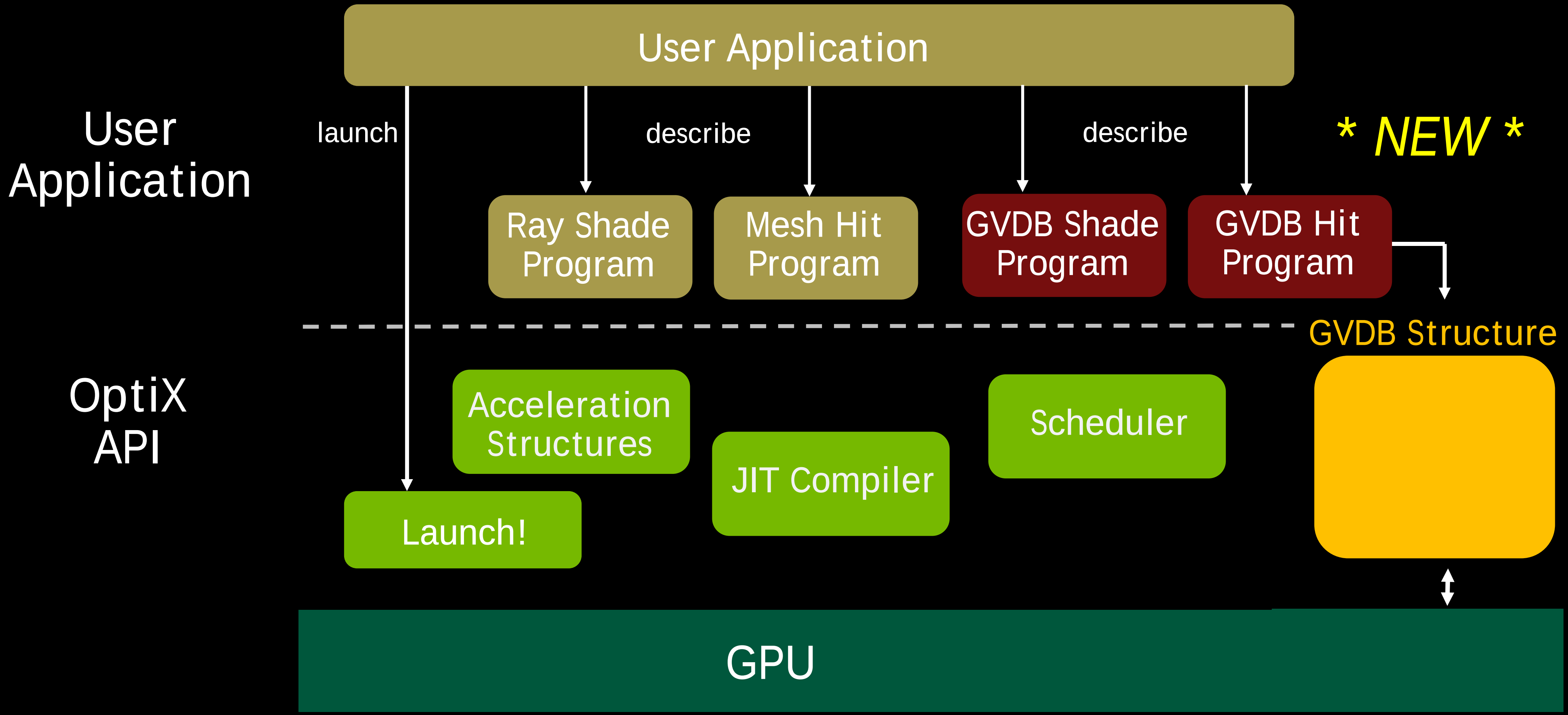
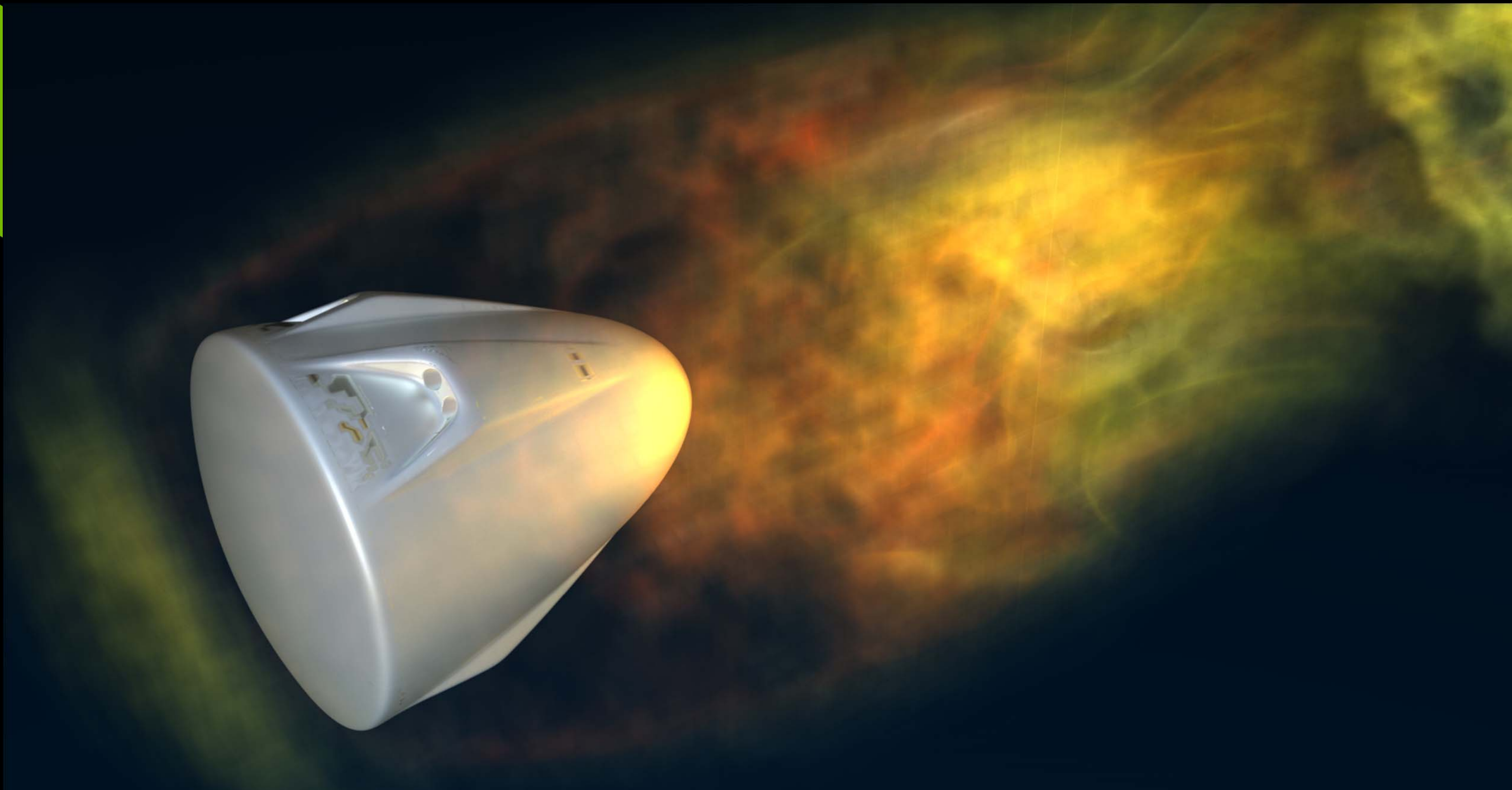
User Application
User Application
launch
describe
Ray Shade Program
Mesh Hit Program
OptiX API
Acceleration Structures
JIT Compiler
Scheduler
Launch!
GPU


User Application
launch
describe
describe
* NEW *
Ray Shade Program
Mesh Hit Program
GVDB Shade Program
GVDB Hit Program
GVDB Structure
OptiX API
Acceleration Structures
JIT Compiler
Scheduler
Launch!
GPU

GPU TECHNOLOGY CONFERENCE



NVIDIA DESIGNWORKS

GVDB SPARSE VOLUMES

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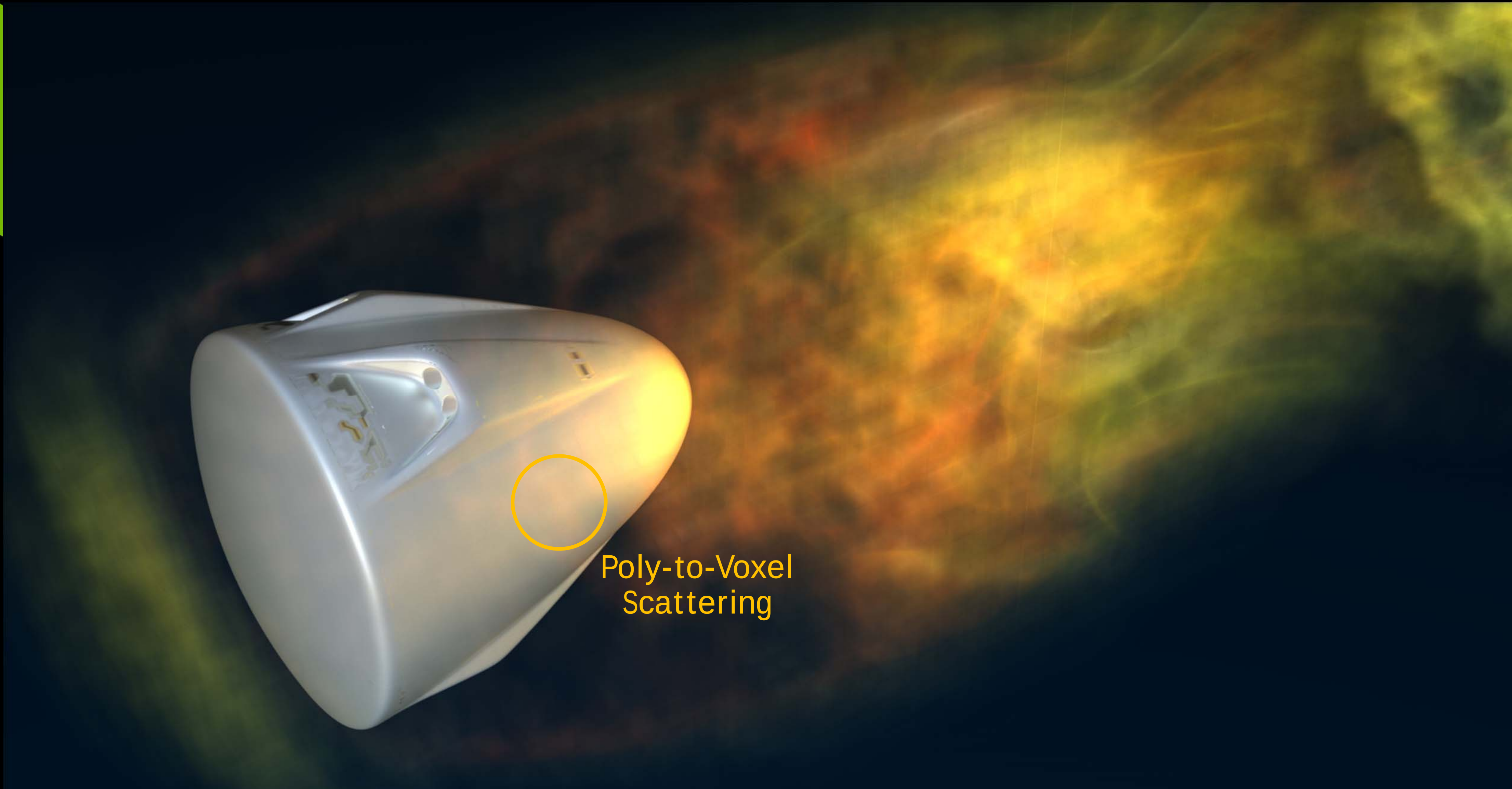
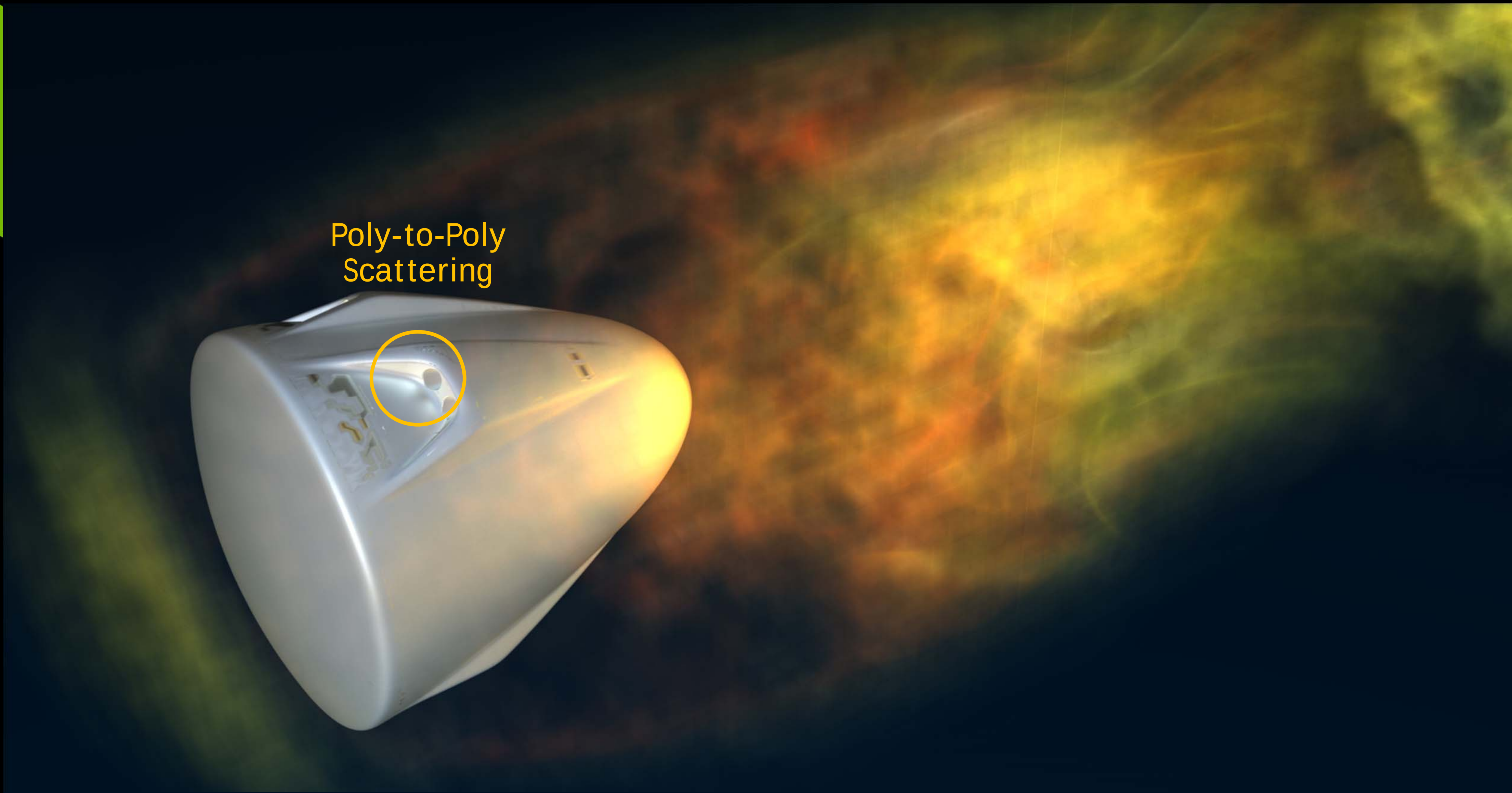
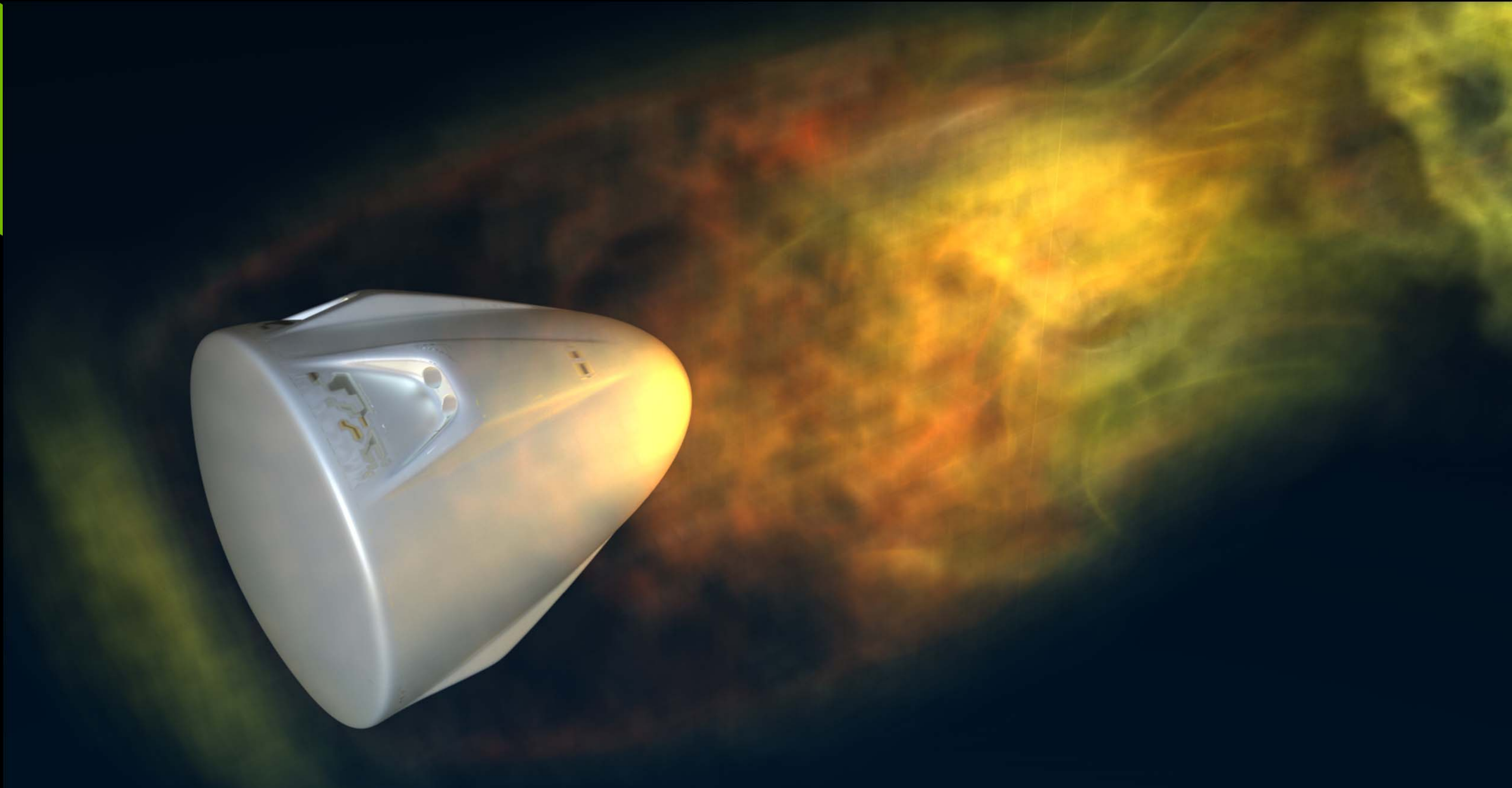



Poly-to-Poly
Scattering

GPU TECHNOLOGY CONFERENCE



NVIDIA GVDB SPARSE VOLUMES

Interested in GVDB?
Let us know!

http://developer.nvidia.com/gvdb

Rama Karl Hoetzlein
NVIDIA

THANKS! TO..

SpaceX

Stephen Jones

Victor X. Guerrero

Andre Kessler

Ken Museth, Dreamworks Animation

NVIDIA

Tom Fogal

Tristan Lorach

Craig Fullman

Steven Parker

NVIDIA IndeX

Christopher Lux

Marc Nienhaus

Tom-Michael Thamm

GVDB SPARSE VOLUMES

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