Cinematic Scientific Visualization in Houdini

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National Center for Supercomputing Applications
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Vocabulary

Renaissance Team *n.*

1. A cross-disciplinary group of experts in science, technology, and art, who work together to build extremely effective science outreach projects.

Vocabulary

Cinematic Scientific Visualization *n.*

1. Production-quality, data-driven imagery created with movie-making tools with good composition, camera direction, and artistic aesthetics suitable for distribution in immersive giant screen theaters.

Scientific Visualization *n.*

1. Imagery created using data with spatial 3D coordinates, often calculated on large computing clusters.

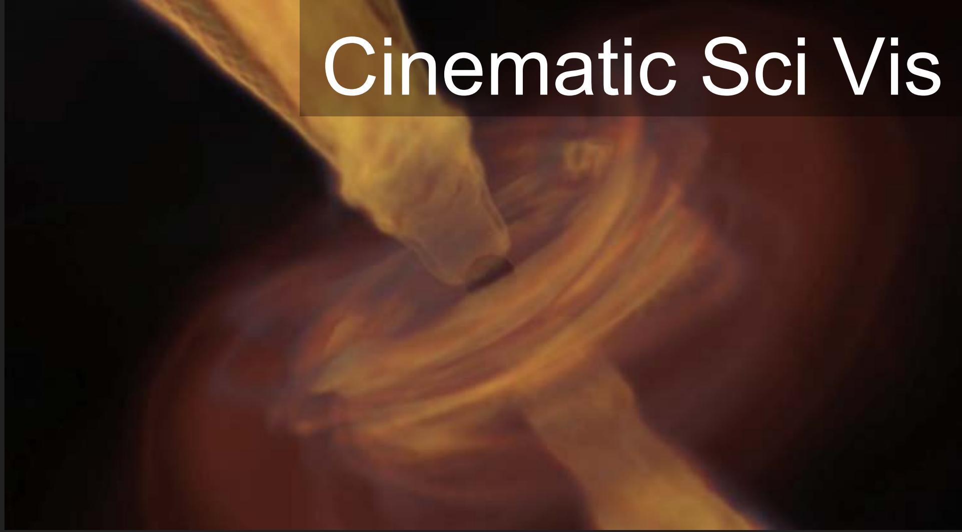
Scientific Illustration *n.*

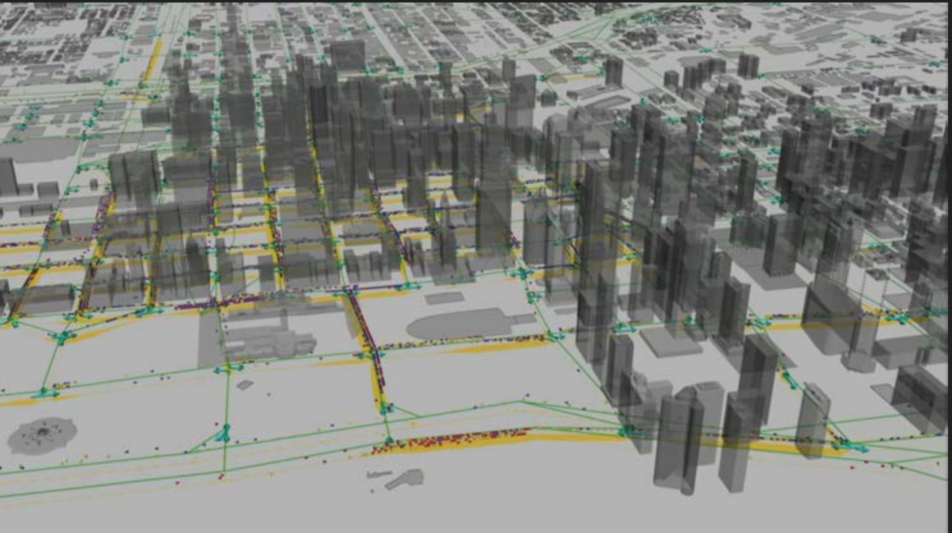
1. Imagery created based on expert input but using predominantly artistic tools.

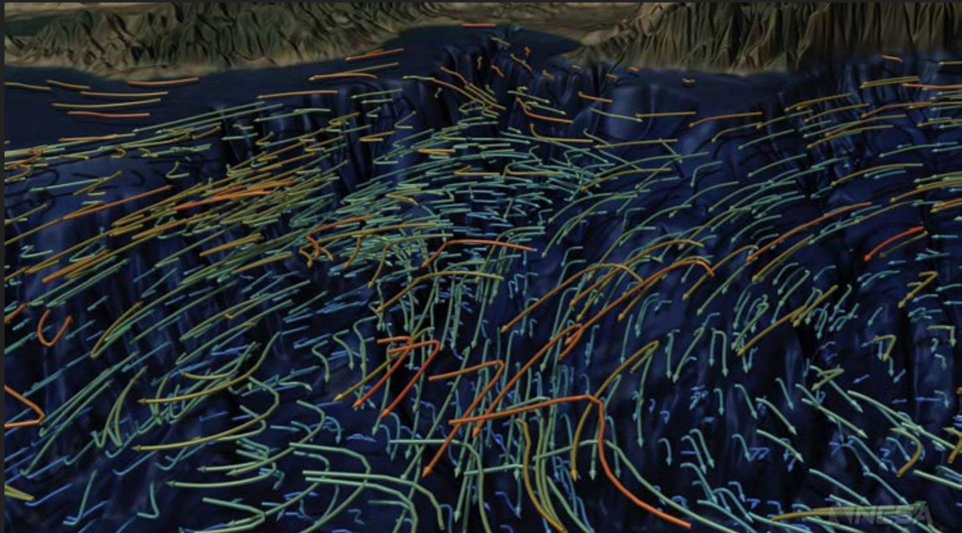
Information Visualization *n.*

1. Imagery created using relational data which often has no direct mapping to spatial coordinates.

Cinematic Sci Vis

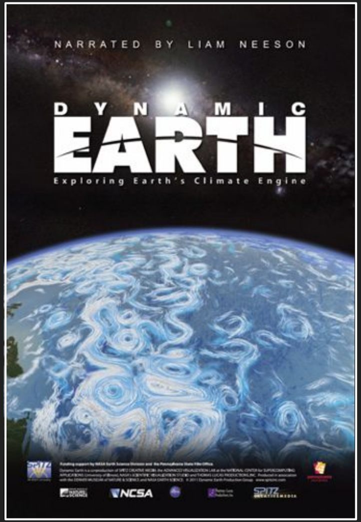


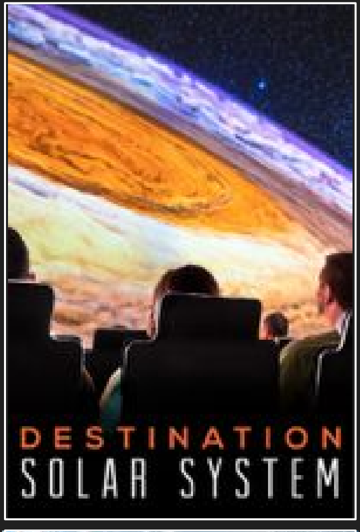


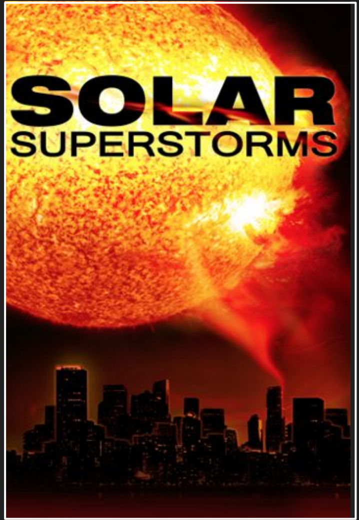


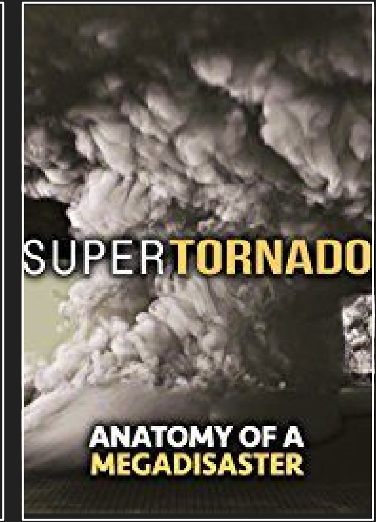

CHANGE YOUR VIEW OF OUR UNIVERSE
IMAX
HUBBLE 3D
NARRATED BY LEONARDO DiCAPRIO
IMAX.COM/HUBBLE

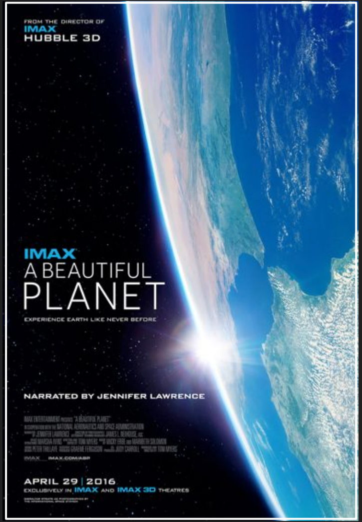

BRAD PITT
SEAN PENN
JESSICA CHASTAIN
THE TREE OF LIFE
TERRENCE MALICK

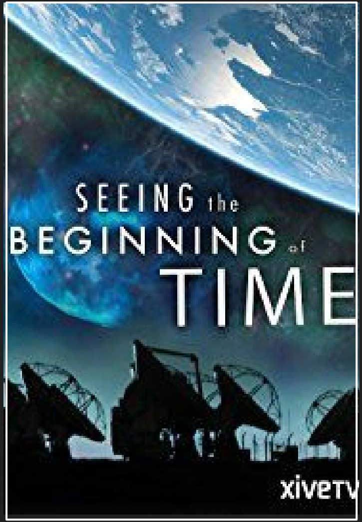

NARRATED BY LIAM NEESON
DYNAMIC
EARTH
Exploring Earth's Climate Engine
NCSA


DESTINATION
SOLAR SYSTEM


SOLAR
SUPERSTORMS


SUPERTORNADO
ANATOMY OF A
MEGADISASTER


FROM THE DIRECTOR OF
IMAX
HUBBLE 3D
IMAX
A BEAUTIFUL
PLANET
EXPERIENCE EARTH LIKE NEVER BEFORE
NARRATED BY JENNIFER LAWRENCE
APRIL 29 | 2016
EXCLUSIVELY IN IMAX AND IMAX 3D THEATRES


SEEING the
BEGINNING of
TIME
xiveTV

Demo Reel **Video**

https://youtu.be/T_0ICxROM0Q

Recent Examples

BIG DATA

Double Coronal Mass Ejection

SIMULATION STATS

DATA SIZE	2.8 TB
TIME STEPS	1794
RESOLUTION	$577R \times 384\theta \times 432\varphi$
SPATIAL SCALE	1x - 6.25x solar radius
TIME SCALE	100 minutes

SCIENTIST	Yuhong Fan
INSTITUTION	Nat. Center for Atmos. Research
SUPERCOMPUTER	Yellowstone, NWSC/NCAR and Discover, NASA Center for Climate Simulation

BIG DATA

El Reno Tornado - May 24, 2011

SIMULATION STATS

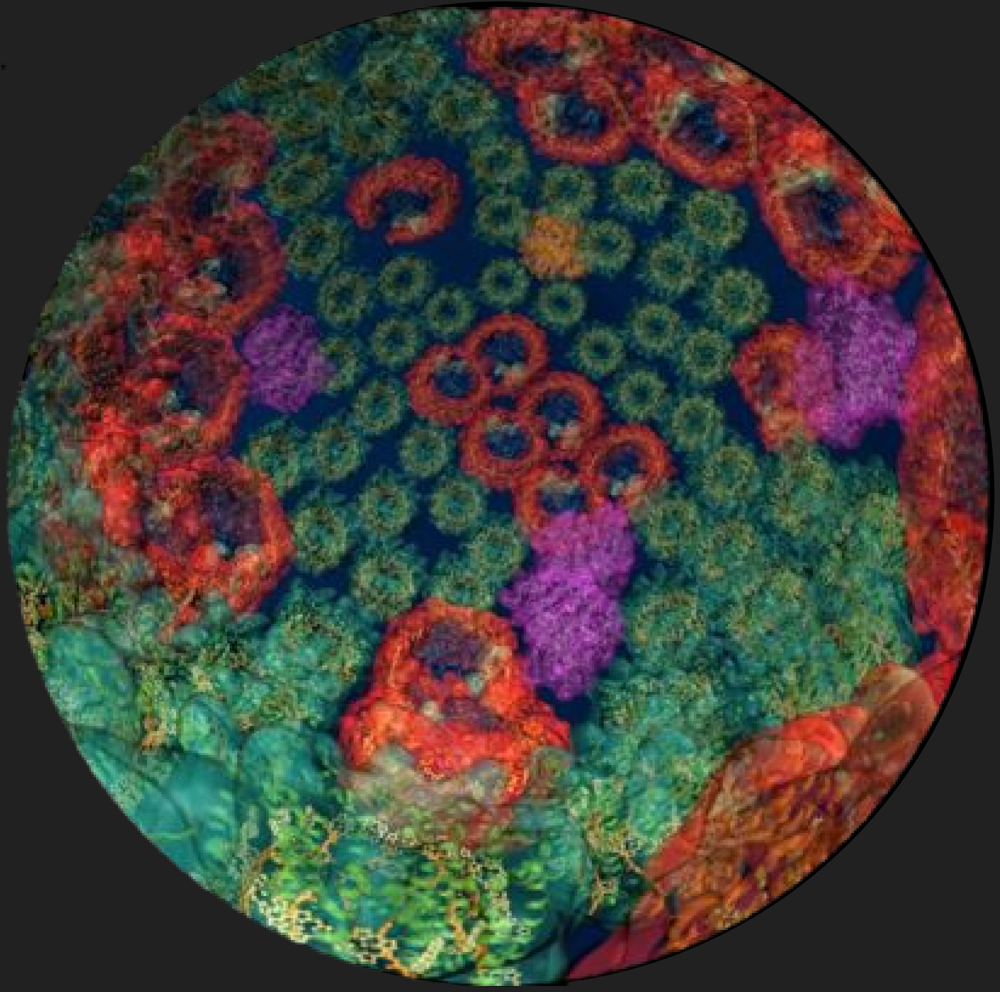
DATA SIZE	160 TB
TIME STEPS	4895
RESOLUTION	1500 x 1500 x 380 stretch grid
SPATIAL SCALE	120km x 120km x 120km
TIME SCALE	2 hours
SCIENTIST	Leigh Orf
INSTITUTION	University of Wisconsin-Madison
SUPERCOMPUTER	Blue Waters, University of Illinois

BIG DATA

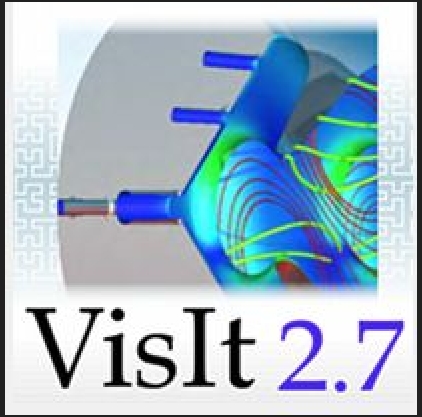
Photosynthetic Organelle

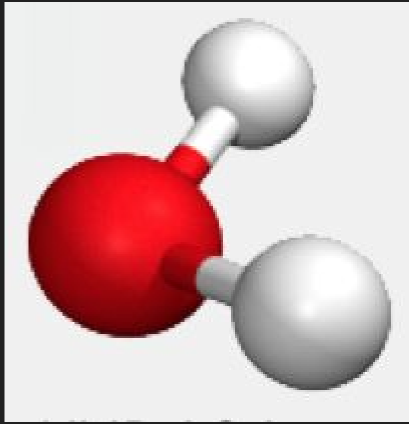
SIMULATION STATS

DATA SIZE	60 TB
TIME STEPS	~100,000
RESOLUTION	~100,000,000 atoms
SPATIAL SCALE	1 Angstrom (1e-10 m)
TIME SCALE	1 femtosecond (1e-15 s)
SCIENTIST	Klaus Schulten
INSTITUTION	University of Illinois at U-C
SUPERCOMPUTER	Blue Waters and Titan

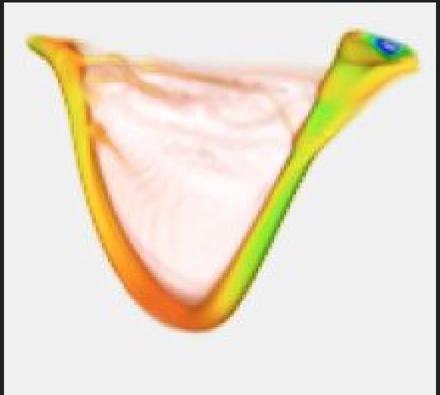


Scientific Visualization Tools





VMD



VAPOR

yt

ParaView

MAYA

Houdini

Nuke

blender™

Ae

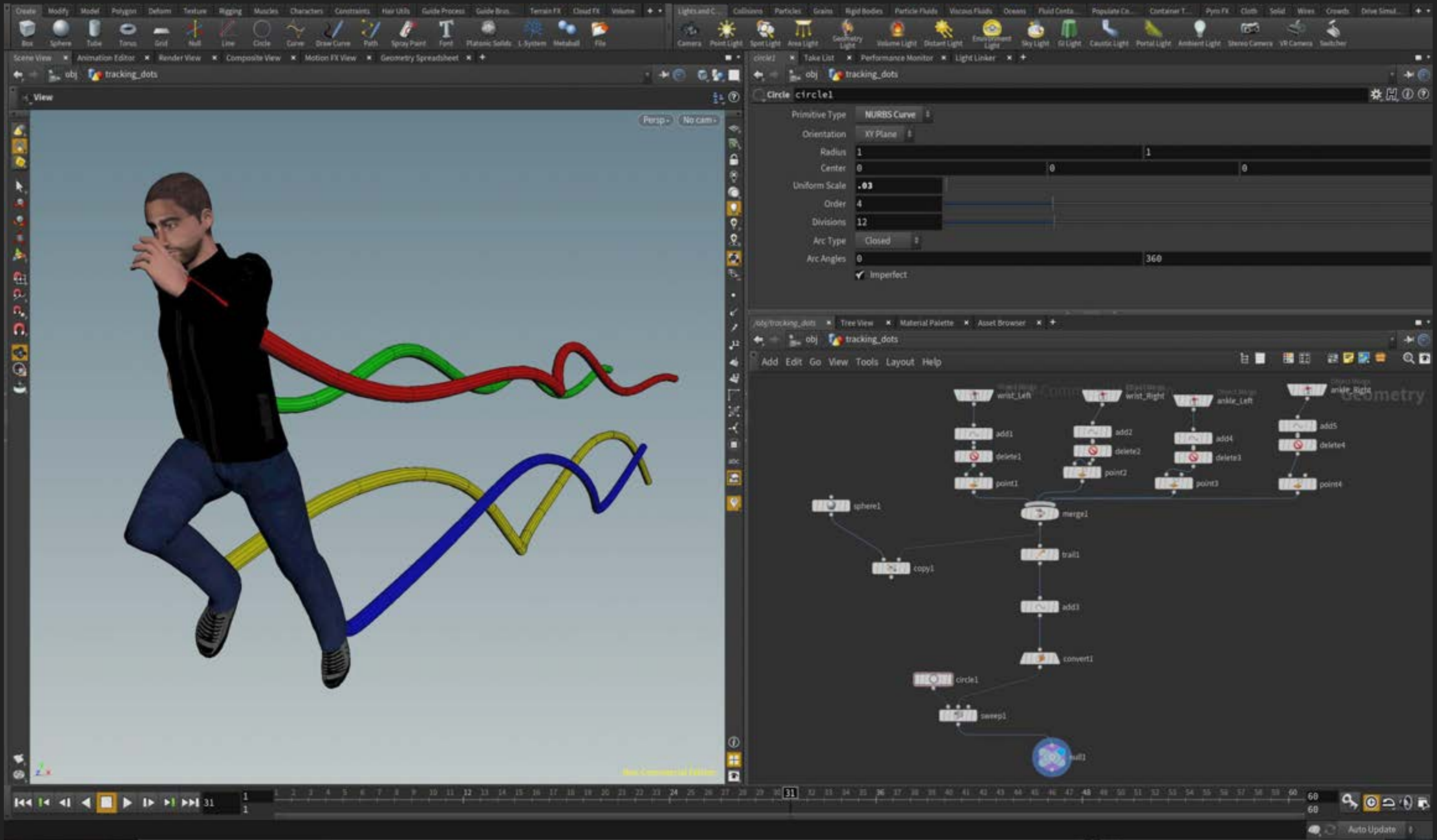
After Effects


scene file
SOPs
ROPs
SHOPs
CHOPs
SOP nodes
Sub-networks
parameters
SOP nodes
Sub-networks
parameters
SOP nodes
Sub-networks
parameters
SOP nodes
Sub-networks
parameters

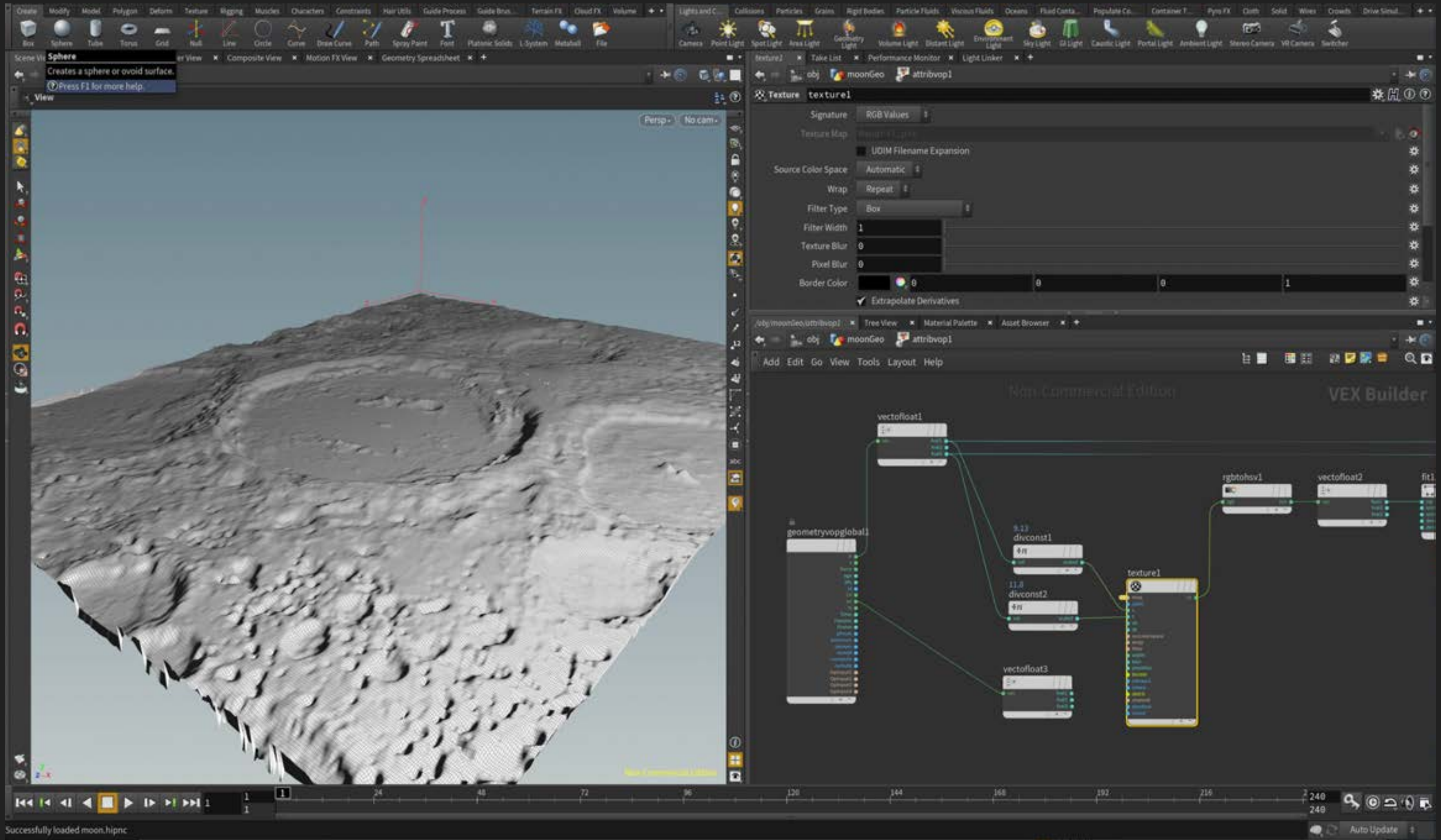
The Houdini Paradigm

Houdini Demos

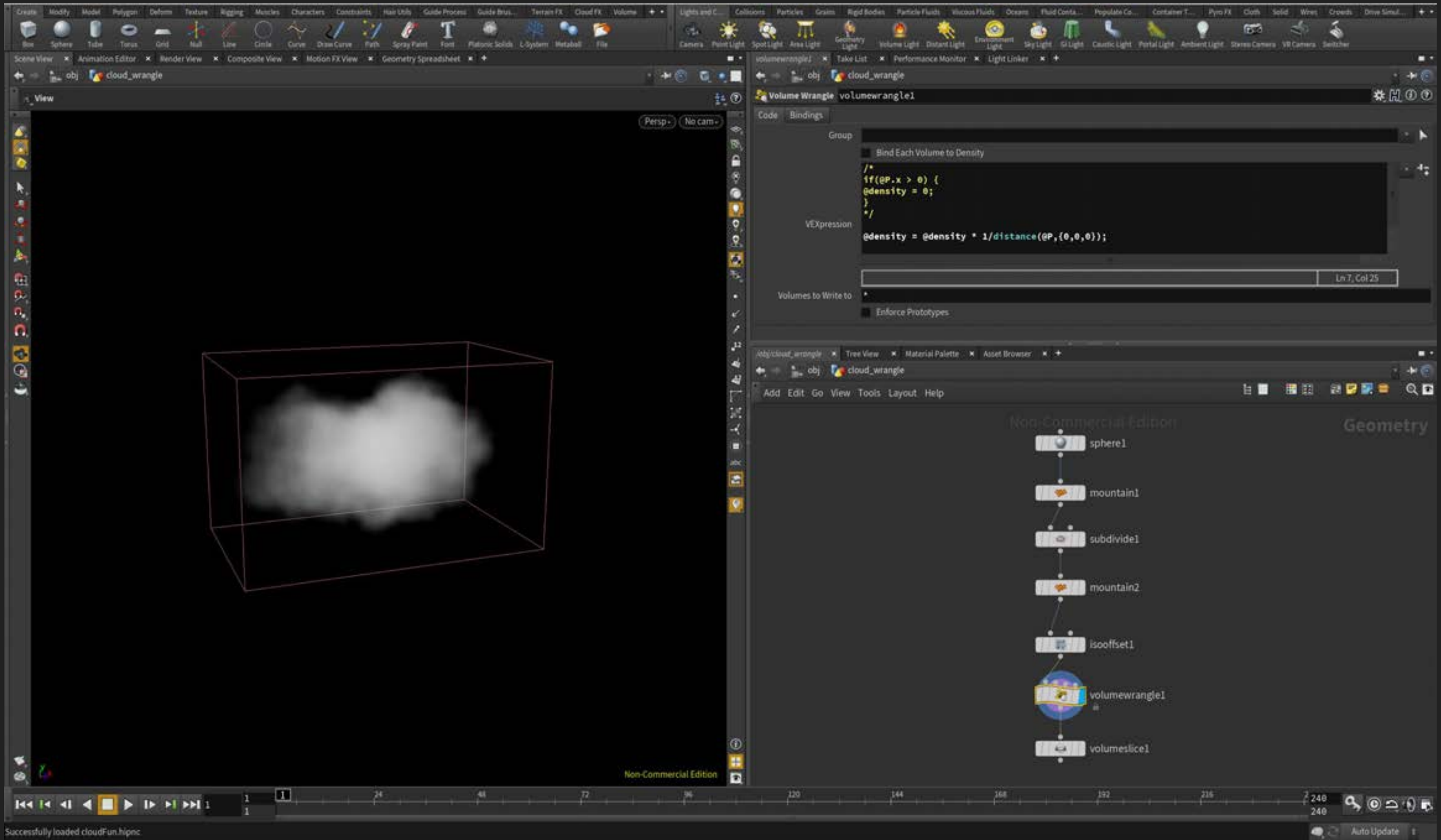
Demo: Deriving Geometry from Data



Demo: Working with External Assets



Demo: Volume and Geometry Manipulation



Programming in Houdini

Ways to Get Your Data into Houdini

A) Custom C++ Plugins
B) Scripting
C) Ytini

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A) Custom C++ Plugins
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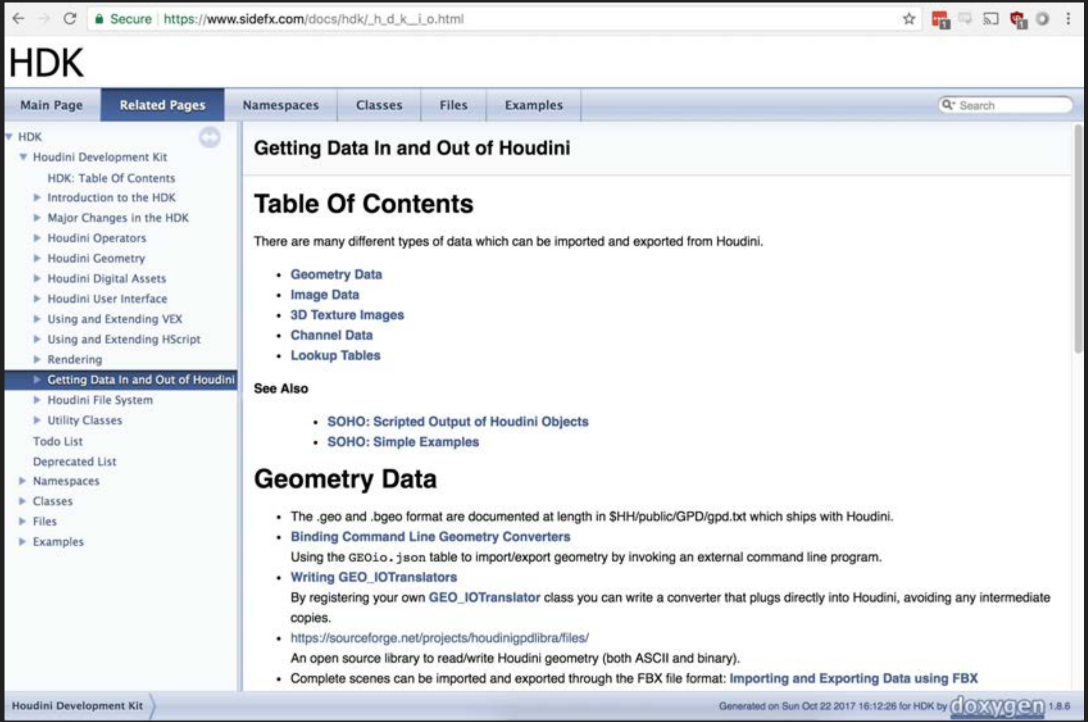
Custom C++ Plugins

Houdini Development Kit (HDK)



Custom C++ Plugins

Houdini Development Kit (HDK)

- Built directly into Houdini, and works seamlessly just like any other feature, without extra or external steps
- Great if you also need custom artistic controls, beyond just reading the data
  - Resolution
  - Interpolation
  - Edge falloff
  - Isovolumes
  - ...

Custom C++ Plugins

Houdini Development Kit (HDK)

- Built directly into Houdini, and works seamlessly just like any other feature, without extra or external steps
- Great if you also need custom artistic controls, beyond just reading the data
  - Resolution
  - Interpolation
  - Edge falloff
  - Isovolumes
  - ...
- Downsides:
  - More programming-intensive than some other solutions
  - Needs to be updated with every Houdini version

Ways to Get Your Data into Houdini

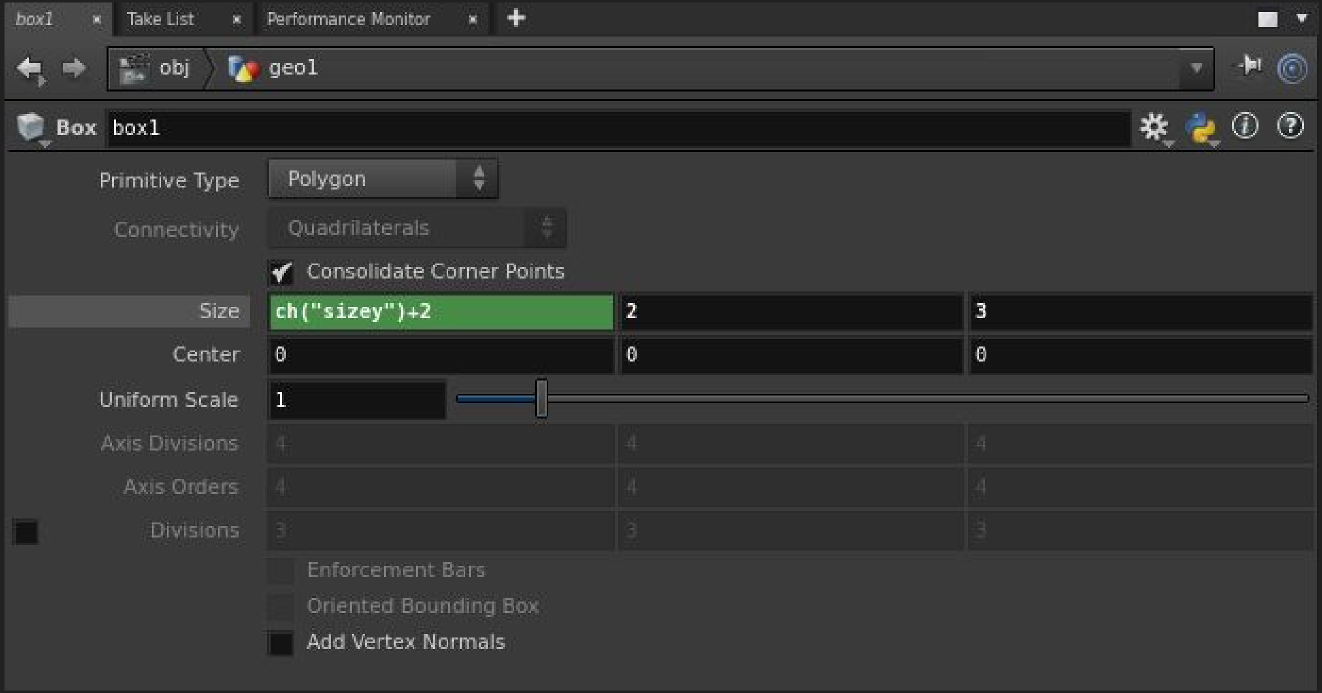
A) Custom C++ Plugins
B) Scripting
C) Ytini

Scripting

- One-time conversion of data into a Houdini-compatible format
  - Have to re-run if you want to make changes
- You can write an external script, or code in Python directly in Houdini

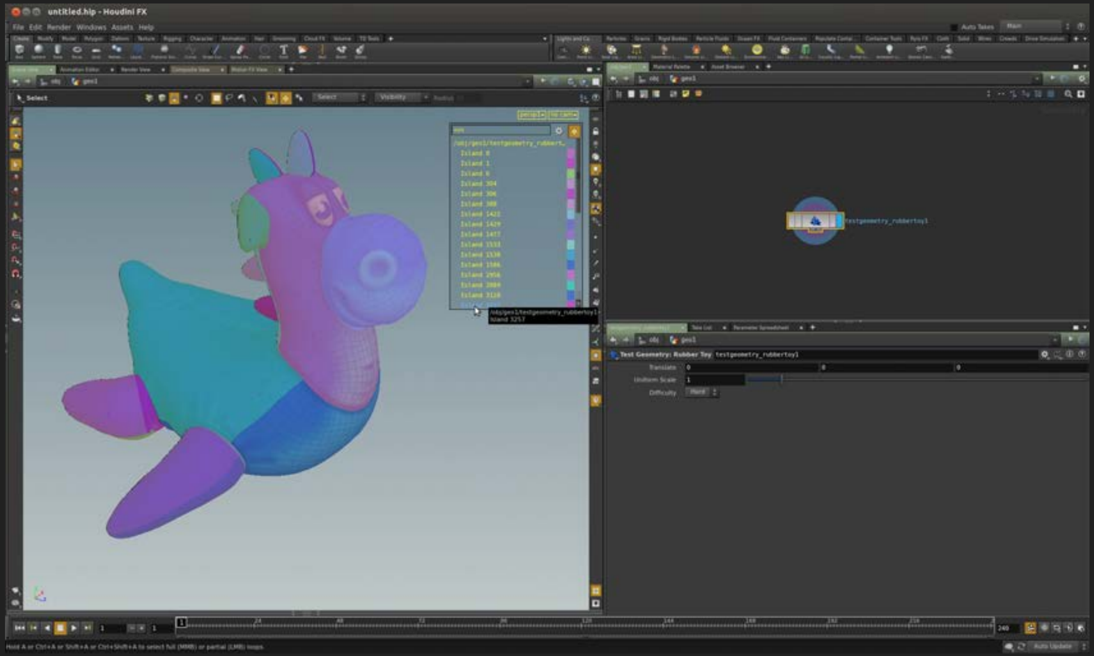
Scripting

- Write script snippets directly in the parameters



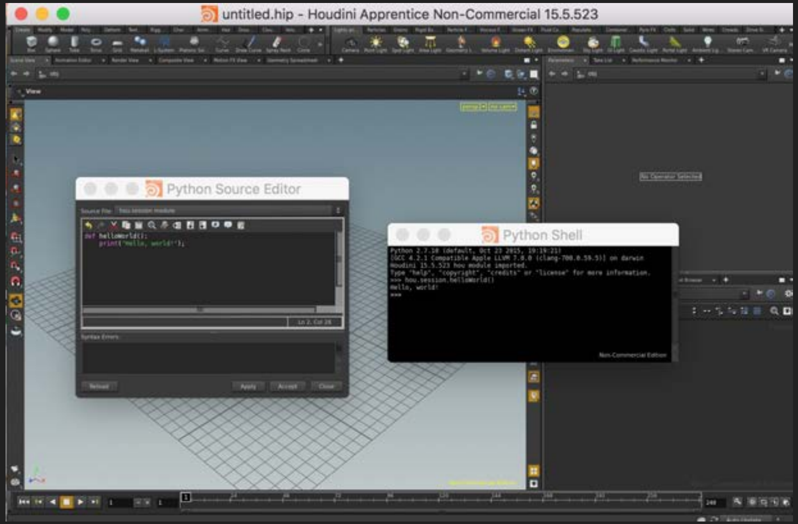
Scripting

- Write script snippets directly in the parameters
- Create your own SOP



Scripting

- Write script snippets directly in the parameters
- Create your own SOP
- Code directly inside Houdini



Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Example .geo volume file

```
PGEOMETRY V2    ← Header
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

← 1 point that defines the center, 1 primitive that is our data volume

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0                                  ← 0 groups
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0        ← 0 extra attributes

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1      ← Center point at (0,0,0) * 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1     ← Volume definition

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

XYZ Resolution: 2x2x2

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Transformation matrix = $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ = identity matrix, which does nothing (no scaling, translating, rotating)

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra
endExtra
```

Other fancy settings include:

- Whether to taper the volume and how much
- What values to set past the border of the volume
- How much lossy compression is allowed
- And more… Described in “GPD.txt” file that comes with Houdini

Example .geo volume file

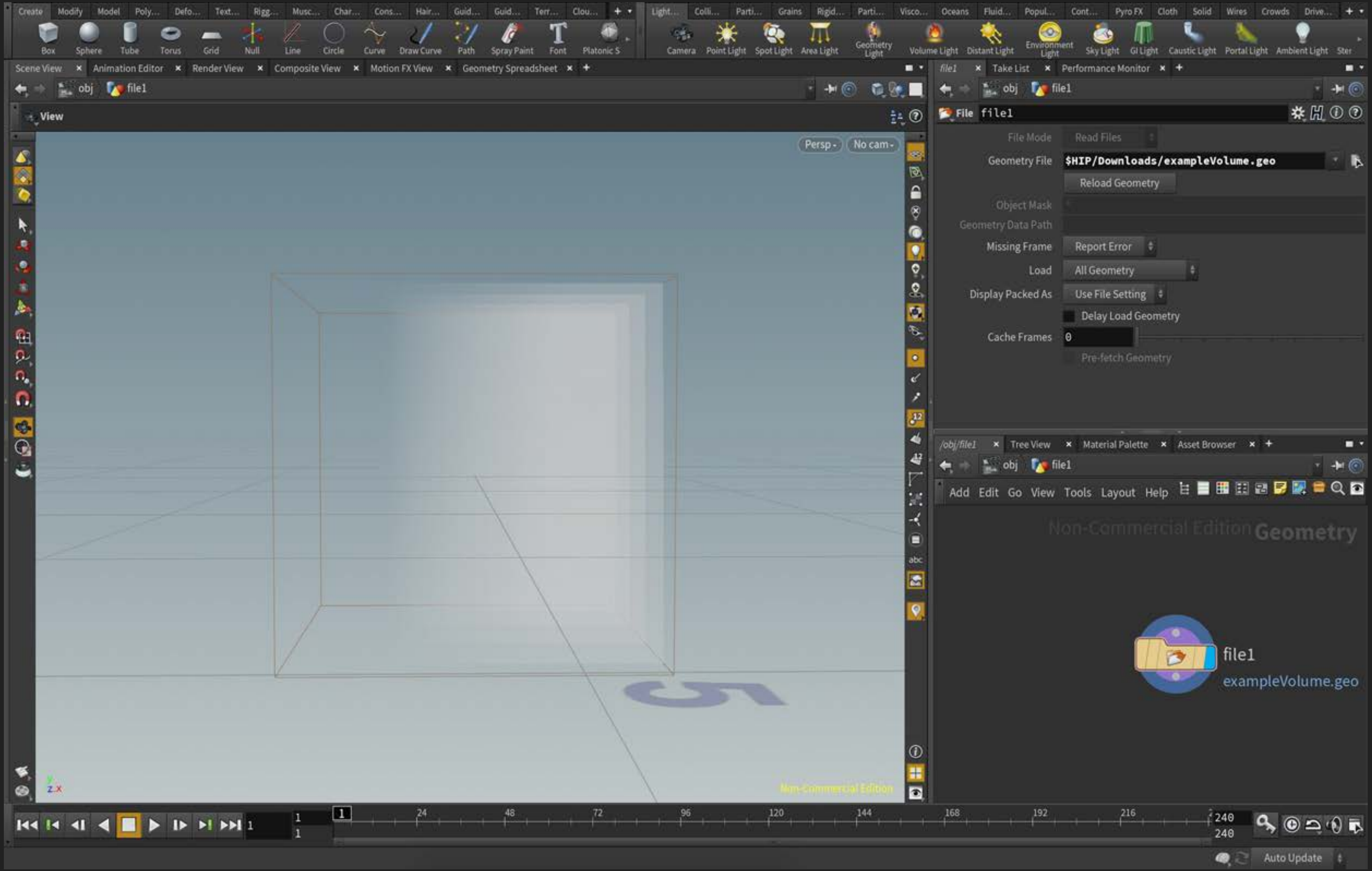
```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1      ← The data

beginExtra
endExtra
```

Example .geo volume file

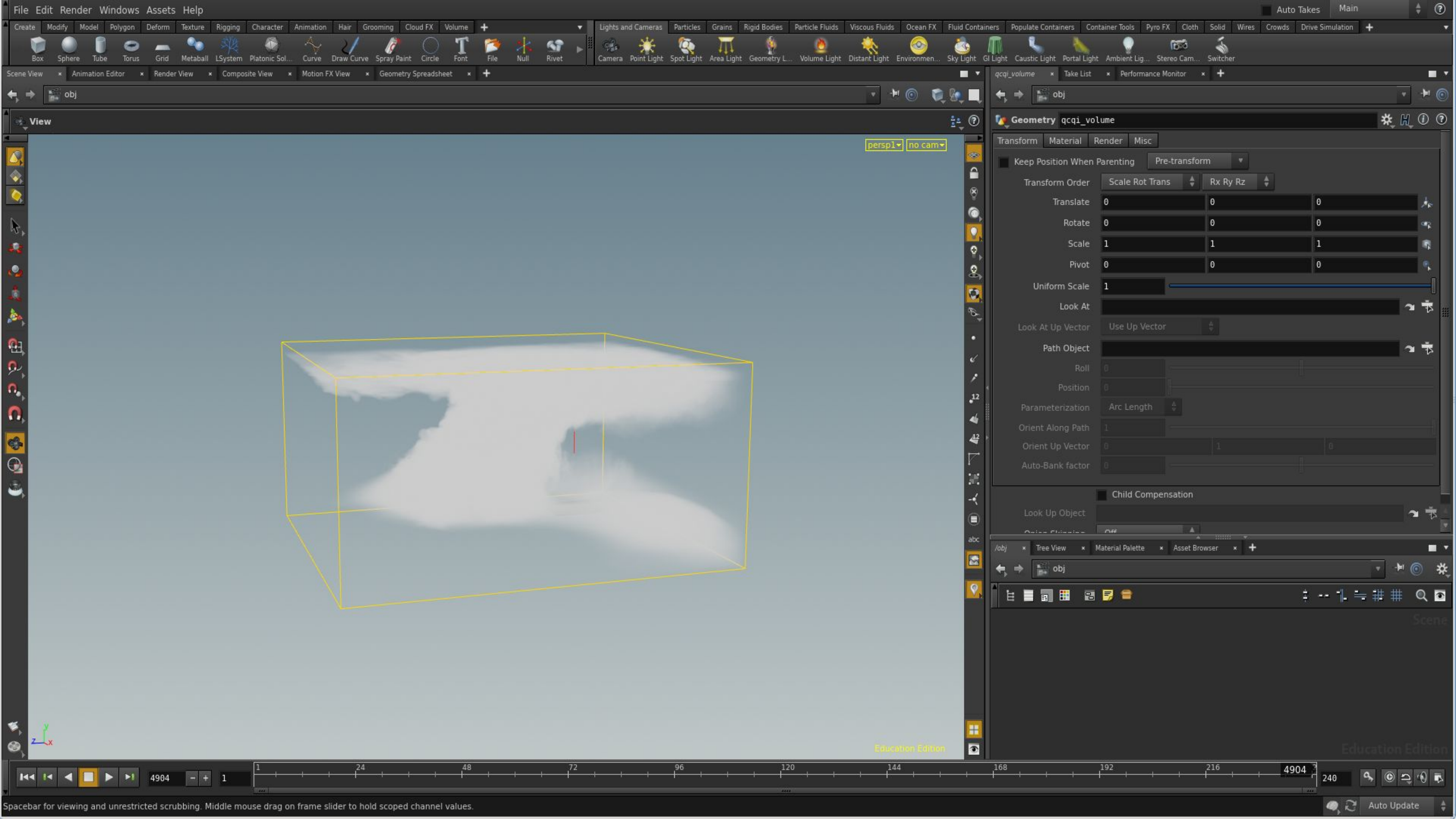
```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1      ← The data. 8 numbers, as defined by the 2*2*2 resolution

beginExtra
endExtra
```

Example .geo volume file

```
PGEOMETRY V2
NPoints 1 NPrims 1
NPointGroups 0 NPrimGroups 0
NPointAttrib 0 NVertexAttrib 0 NPrimAttrib 0 NAttrib 0

0 0 0 1

Volume 0 1 0 0 0 1 0 0 0 1 -2 2 2 2 constant 0 0 smoke 0 1

0 1 0 1 0 1 0 1

beginExtra     ← End / extras
endExtra
```


Create
Modify
Model
Box
Sphere
Tube
Torus
Grid
Null
Line
Circle
Curve
Draw Curve
Path
Spray Paint
Font
Camera
Point Light
Spot Light
Area Light
Geometry Light
Volume Light
Distant Light
Environment Light
Sky Light
GI Light
Caustic Light
Portal Light
Ambient Light
Scene View
Animation Editor
Render View
Composite View
Motion FX View
Geometry Spreadsheet
obj
file1
View
Persp
No cam
Take List
Performance Monitor
File file1
File Mode
Read Files
Geometry File
$HIP/Downloads/exampleVolume.geo
Reload Geometry
Object Mask
Geometry Data Path
Missing Frame
Report Error
Load
All Geometry
Display Packed As
Use File Setting
Delay Load Geometry
Cache Frames
0
Pre-fetch Geometry
/obj/file1
Tree View
Material Palette
Asset Browser
Add
Edit
Go
View
Tools
Layout
Help
Non-Commercial Edition
Geometry
file1
exampleVolume.geo
Auto Update

Let’s Play with Real Data: Hands-on Demo


File Edit Render Windows Assets Help
Auto Takes
Main
Create Modify Model Polygon Deform Texture Rigging Character Animation Hair Grooming Cloud FX Volume
Box Sphere Tube Torus Grid Metaball LSystem Platonic Sol... Curve Draw Curve Spray Paint Circle Font File Null Rivet
Lights and Cameras Particles Grains Rigid Bodies Particle Fluids Viscous Fluids Ocean FX Fluid Containers Populate Containers Container Tools Pyro FX Cloth Solid Wires Crowds Drive Simulation
Camera Point Light Spot Light Area Light Geometry L... Volume Light Distant Light Environmen... Sky Light GI Light Caustic Light Portal Light Ambient Lig... Stereo Cam... Switcher
Scene View Animation Editor Render View Composite View Motion FX View Geometry Spreadsheet
obj
View
persp1
no cam
Education Edition
qcqi_volume Take List Performance Monitor
Geometry qcqi_volume
Transform Material Render Misc
Keep Position When Parenting
Pre-transform
Transform Order
Scale Rot Trans
Rx Ry Rz
Translate 0 0 0
Rotate 0 0 0
Scale 1 1 1
Pivot 0 0 0
Uniform Scale 1
Look At
Look At Up Vector
Use Up Vector
Path Object
Roll
Position
Parameterization
Arc Length
Orient Along Path
Orient Up Vector
Auto-Bank factor
Child Compensation
Look Up Object
/obj Tree View Material Palette Asset Browser
4904
1
24 48 72 96 120 144 168 192 216
240
Spacebar for viewing and unrestricted scrubbing. Middle mouse drag on frame slider to hold scoped channel values.
Auto Update

Ways to Get Your Data in Houdini

A) Custom C++ Plugins
B) Scripting
C) Ytini

ytini

ytini

(yt + Houdini™)

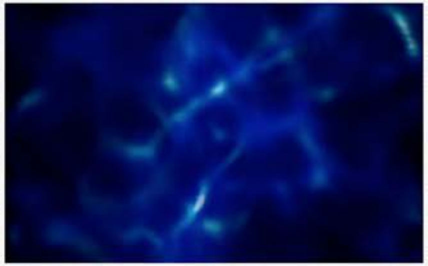
```
[kalina@theviz Documents]$ python
Python 2.7.11 |Continuum Analytics, Inc.| (default, Dec  6 2015, 18:08:32)
[GCC 4.4.7 20120313 (Red Hat 4.4.7-1)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
Anaconda is brought to you by Continuum Analytics.
Please check out: http://continuum.io/thanks and https://anaconda.org
>>> import yt
>>> ds = yt.load('/home/kalina/Downloads/sedov_hdf5_chk_0001')
yt : [INFO     ] 2017-05-09 15:54:35,873 Particle file found: sedov_hdf5_chk_0001
yt : [INFO     ] 2017-05-09 15:54:35,885 integer runtime parameter checkpointfilenumber overwrites a simulation
yt : [INFO     ] 2017-05-09 15:54:35,885 integer runtime parameter plotfilenumber overwrites a simulation scalar
yt : [INFO     ] 2017-05-09 15:54:35,914 Parameters: current_time              = 0.0100075930657
yt : [INFO     ] 2017-05-09 15:54:35,914 Parameters: domain_dimensions         = [8 8 8]
yt : [INFO     ] 2017-05-09 15:54:35,915 Parameters: domain_left_edge          = [ 0.  0.  0.]
yt : [INFO     ] 2017-05-09 15:54:35,915 Parameters: domain_right_edge         = [ 1.  1.  1.]
yt : [INFO     ] 2017-05-09 15:54:35,916 Parameters: cosmological_simulation   = 0.0
>>> ds.print_stats()
level   # grids        # cells       # cells^3
----------------------------------------------
  0          1            512              8
  1          8           4096             16
  2         64          32768             32
  3        256         131072             51
----------------------------------------------
           329         168448


t = 1.00075931e-02 = 1.00075931e-02 s = 3.17121488e-10 years

Smallest Cell:
        Width: 5.064e-27 Mpc
        Width: 5.064e-21 pc
        Width: 1.044e-15 AU
        Width: 1.562e-02 cm
>>> 
```

yt → OpenVDB → Houdini™

Ytini.com

1.1 The Data

Begin by downloading the Enzo Tiny Cosmology sample dataset from here. Take note of the directory where this is being saved. Go there, and unzip the folder.



1.2 The Code


```
#! /usr/bin/env python
import sys
import pyopenvdb as vdb
import numpy as np
import yt
from math import ceil


#####################################################################
### Modify these values to point to your own data on your own machine ###
#####################################################################

datafilename = '/home/kalina/Downloads/enzo_tiny_cosmology/DD0010/DD0010'
outfilepath = '/fe2/amr/data/tutorial'
variable = 'Density'

#####################################################################
#####################################################################


#Load data
ds = yt.load(datafilename)
```

Download the writeAMRVDB.py Python script from our Bitbucket repository. Take note of the directory where this is being saved.

Open the file in a text editor. Search for the line that starts with `datafilename =`. Write in the path to the data file you downloaded.

Search for the line that starts with `outfilepath =`. Write in the path to the directory where you want to write the output VDB files.

Rendering in Houdini

Demo: Camera, Lighting, and Render Setup