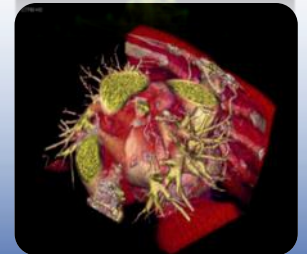
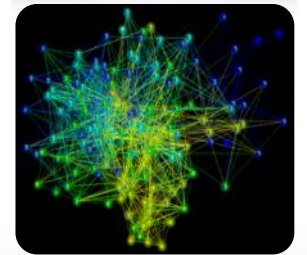
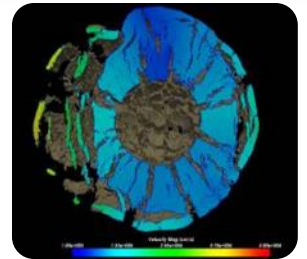
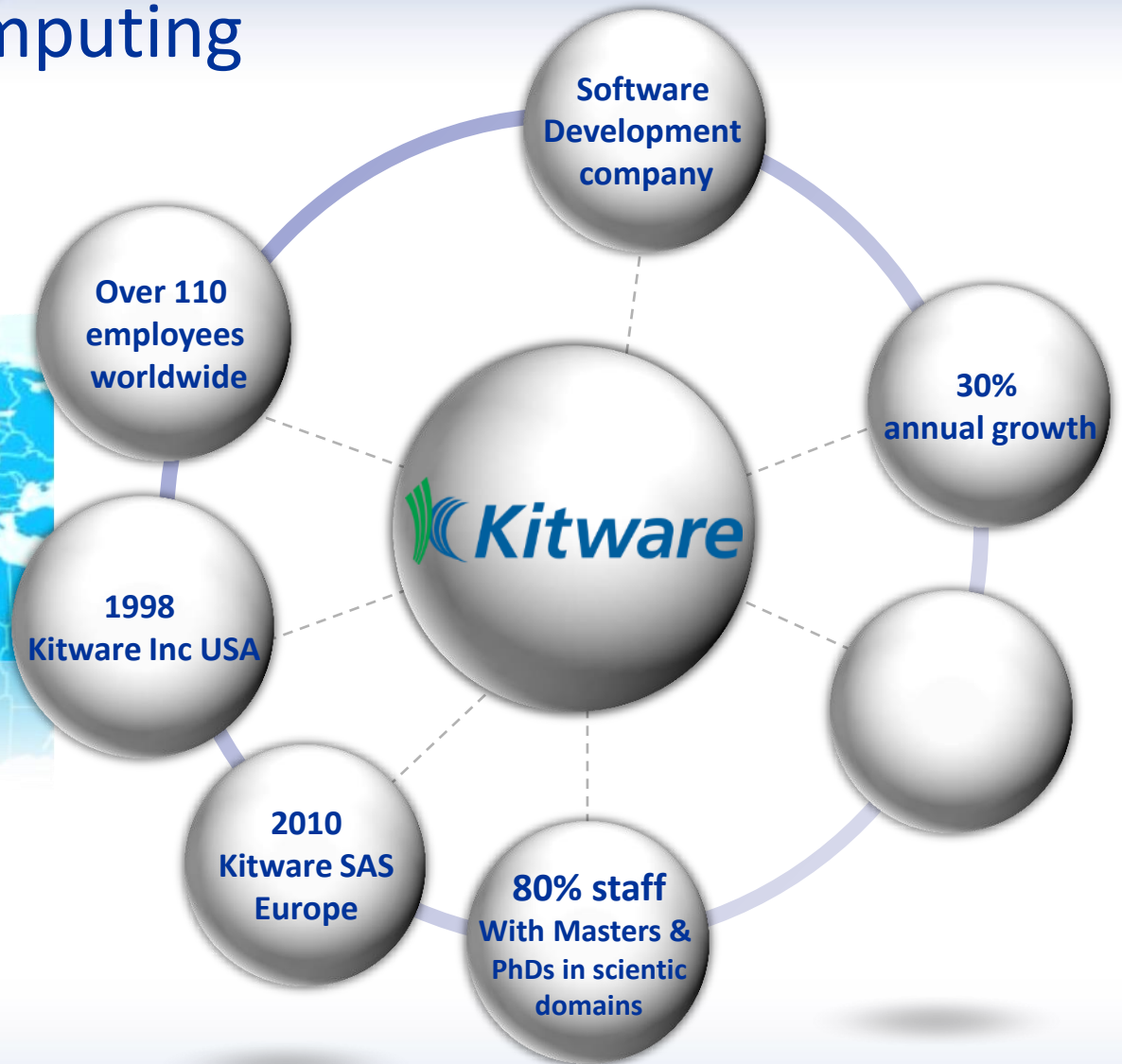


# Post-processing and Visualization with Open-Source Tools

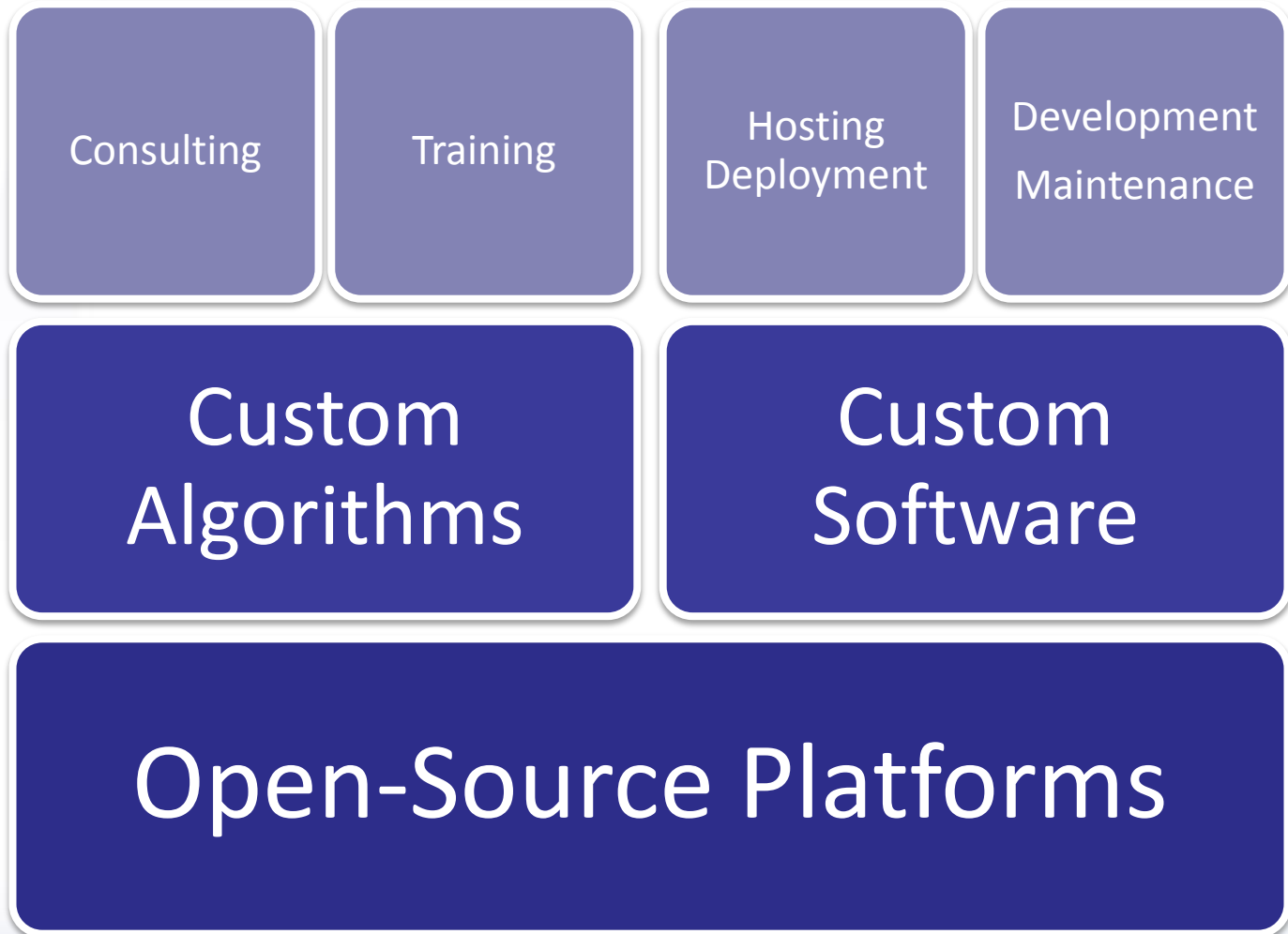
Journée Scientifique Centre Image  
April 9, 2015 - Julien Jomier



# Kitware - Leader in Open Source Software for Scientific Computing



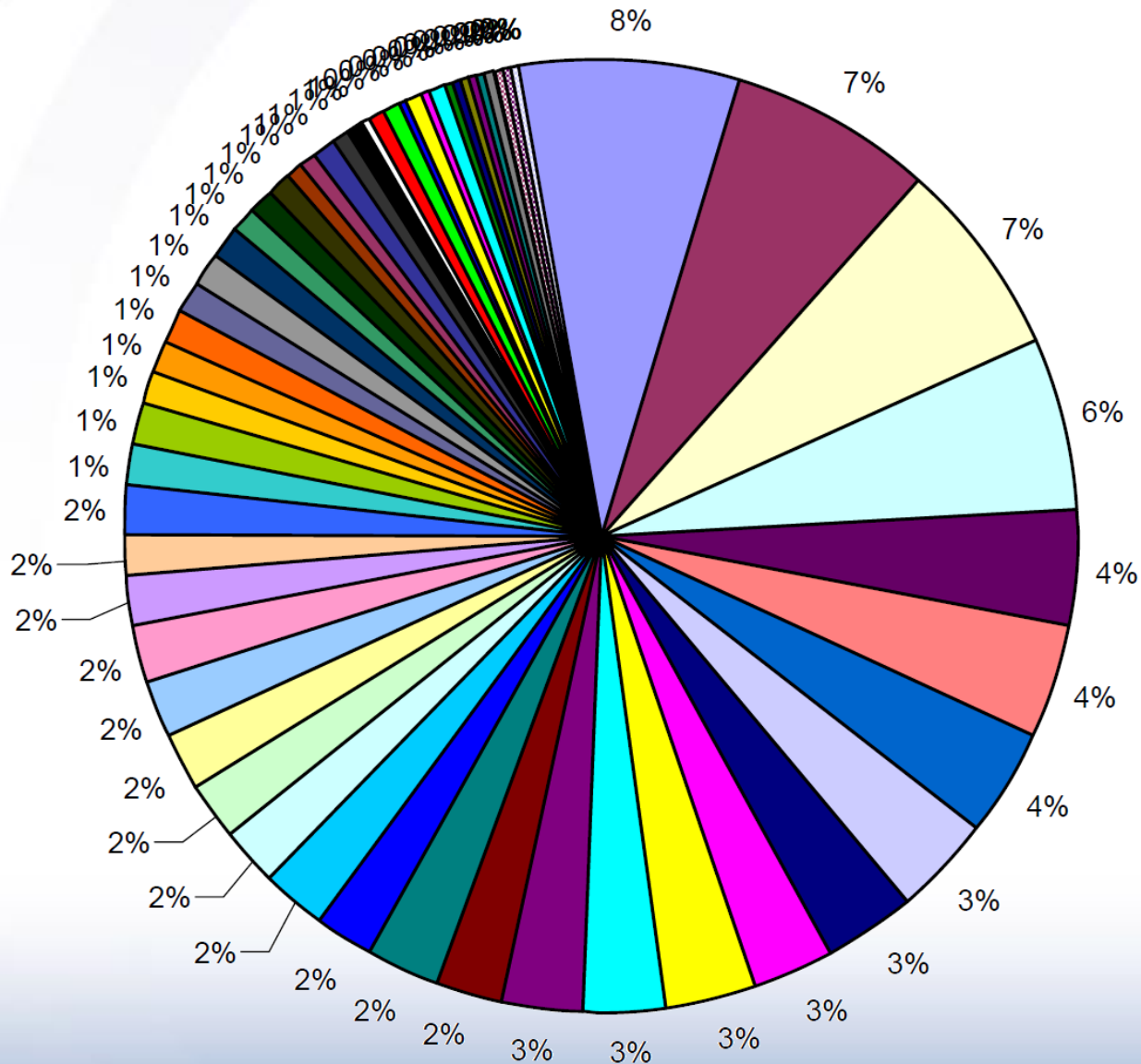
# Kitware - Solutions based on Open-Source Software



# Kitware - Fields of Expertise



# Kitware Open Source Projects







# Challenges of Visualization

- Heterogeneous data
- Large/many/big data
- Distributed data
- Computing resources
- Domain-specific
- User-specific
- Heterogeneous devices
- Uncertainties



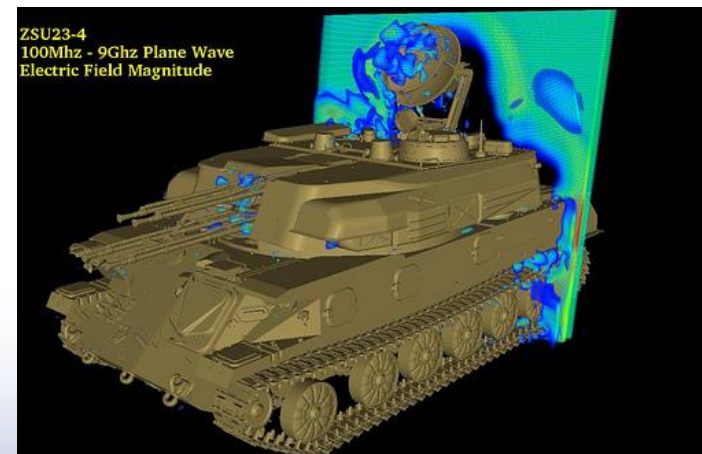
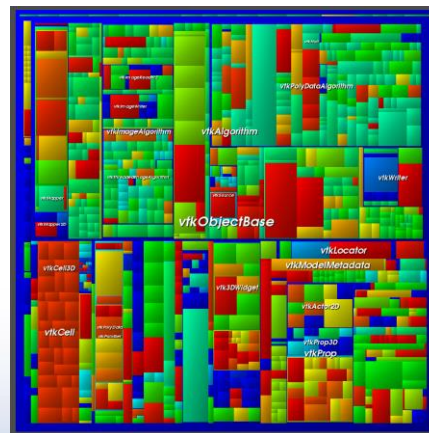
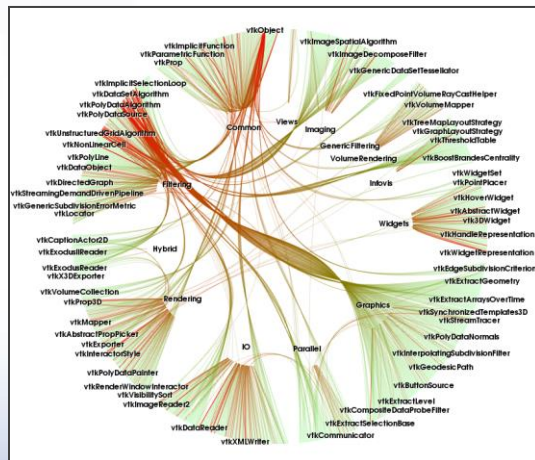
**TOOLS CAN HELP OVERCOME  
THESE CHALLENGES**





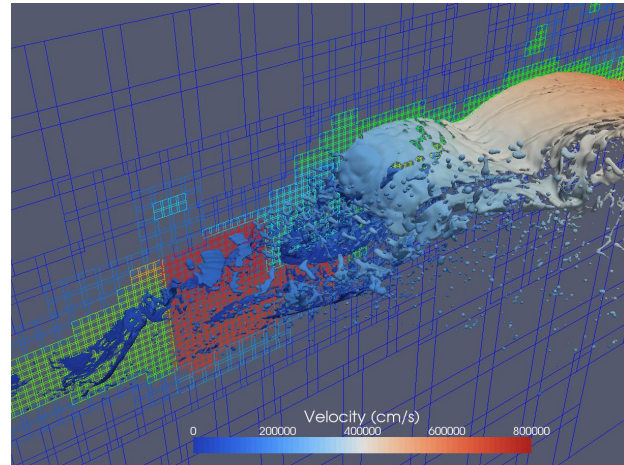
# The Visualization Toolkit (VTK)

- [www.vtk.org](http://www.vtk.org)
- Started in 1993 at GE
- Visualization Library
  - Written in C++ (+8.2 million LOC) – BSD License
  - Automatic binding for Java, Python, C#, TCL
  - Portable by design: Linux, Windows, Mac OSX, Solaris...
- Very active community: 4000+ users on the mailing list

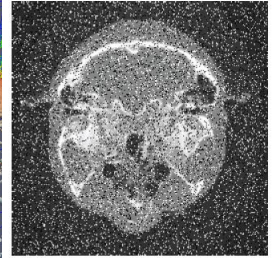


# What can VTK do for me?

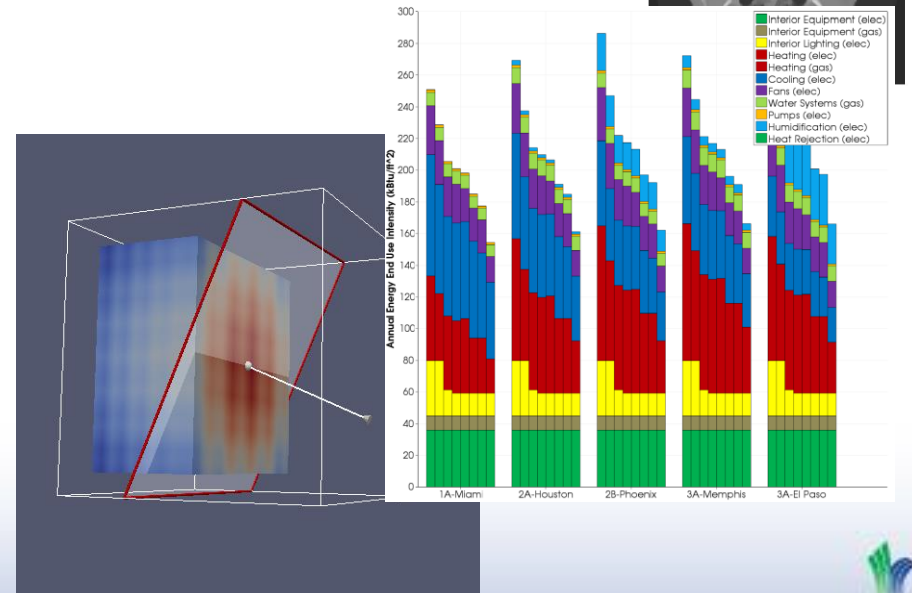
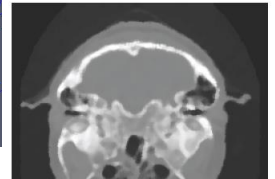
- **Scientific Visualization**
  - 2D to 4D data processing and (volume) rendering
  - Image processing
- **Information Visualization**
  - Charting/plotting
- **Application support**
  - GUI support, Widgets
- **Toolkit**
  - Meant to be integrated



Noisy Image



Median Smoothing



# Design Philosophy

- Underlying theme is to **process data**
  - Find the salient features
  - Produce imagery that conveys meaning
- An open-ended architecture used to **construct programs**
  - These programs usually give interactive controls to the user
  - Let the end user do the searching, **visually**
- Modular architecture
  - Modules implemented in Object-Oriented Classes
  - Pipeline: Data flows through modules in a pipeline
  - Lazy evaluation: Only process what is changed (for big data)



# VTK Main Components

- **Data structures**
  - How VTK stores/provides access to arbitrary data
- **Algorithms/filtering pipeline**
  - Manipulate data
  - Readers, sources, filters, writers
- **Rendering classes**
  - Display that data on the screen
  - Mappers, actors, lights, cameras, renderers
- **Interaction classes**
  - Events, interactors, widgets
- **Application support**
  - Views, representations, Qt and MFC interfaces, wrapping



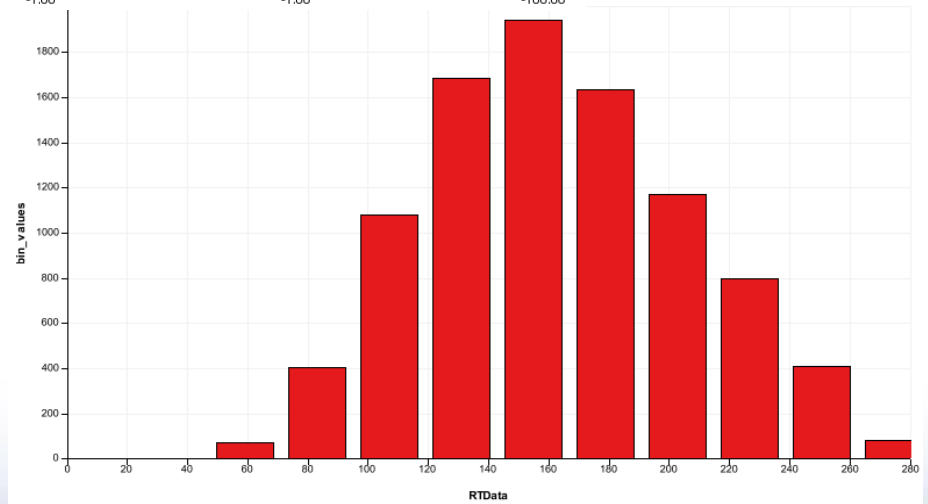
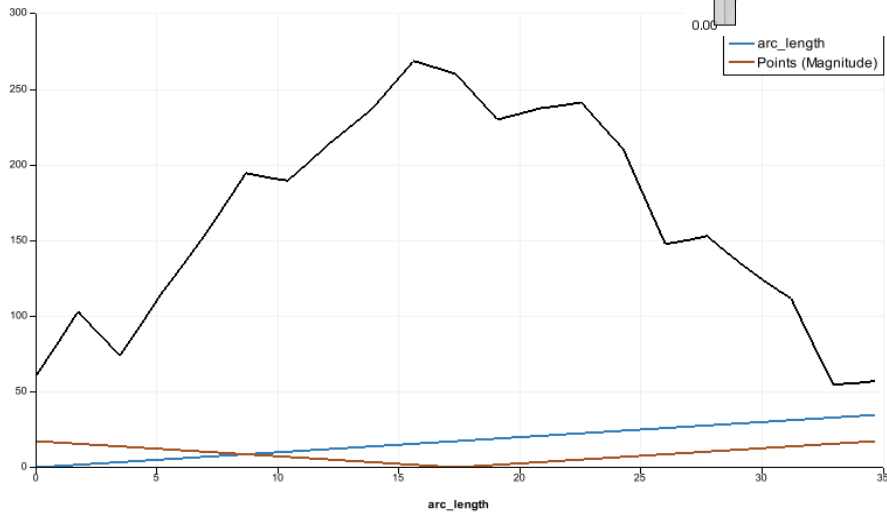
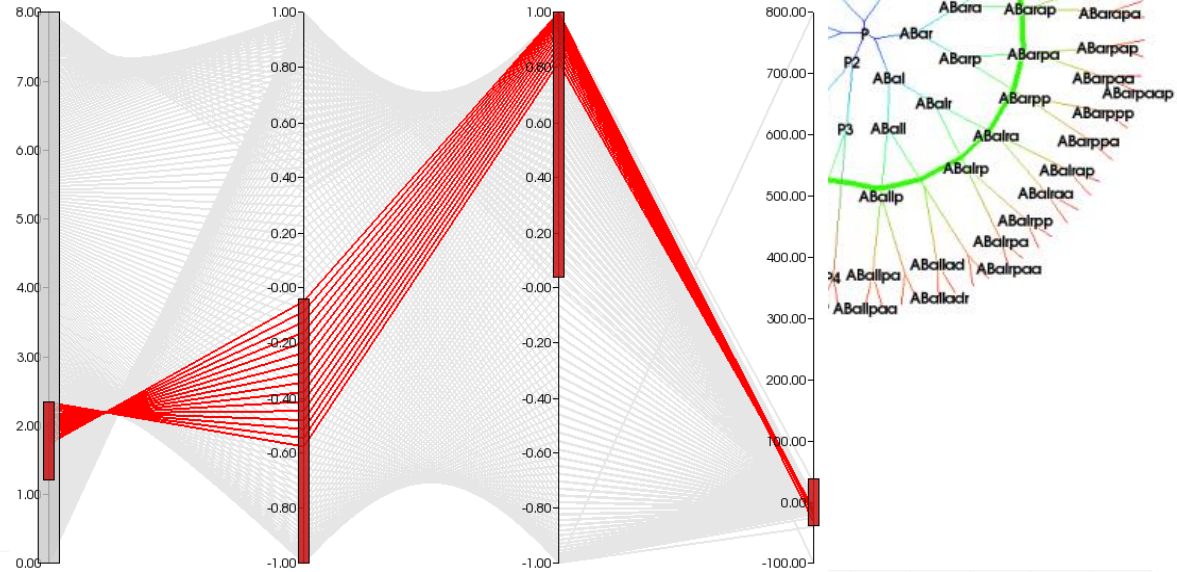
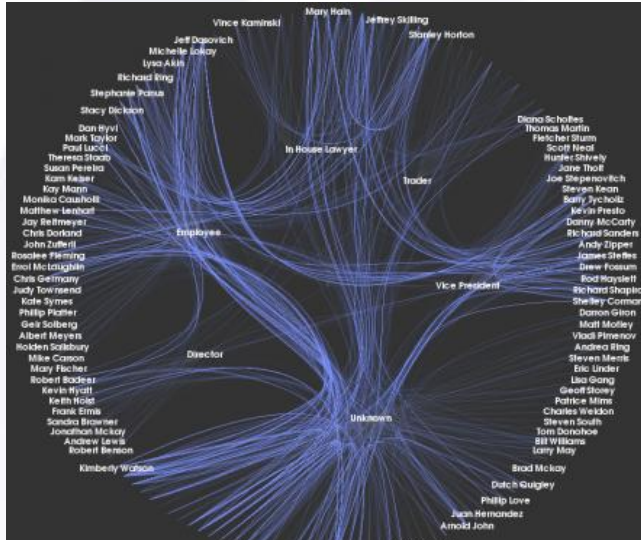
# VTK Main Components

- **140 Readers**
  - STL, EnSight, TecPlot, BMP, JPEG...
- **150 Filters**
  - Contour, Subdivision, Delaunay, Elevation...
  - Statistics, Parallel, Geometry, FlowPaths, Extraction...
- **40 Widgets**
  - Distance, Angle, Plane, Seed, Checkerboard
- **Application domains**
  - Geo visualization
  - Chemistry
  - Imaging

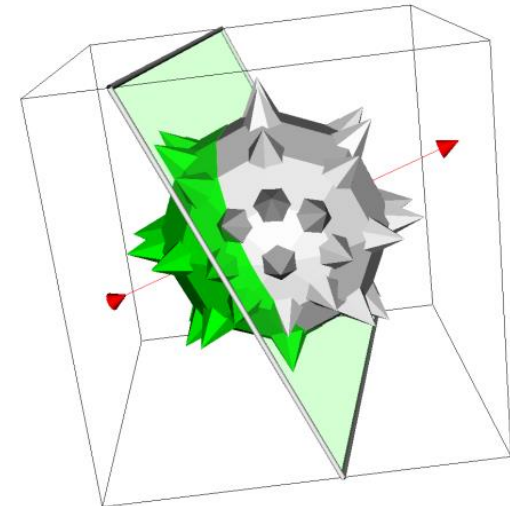
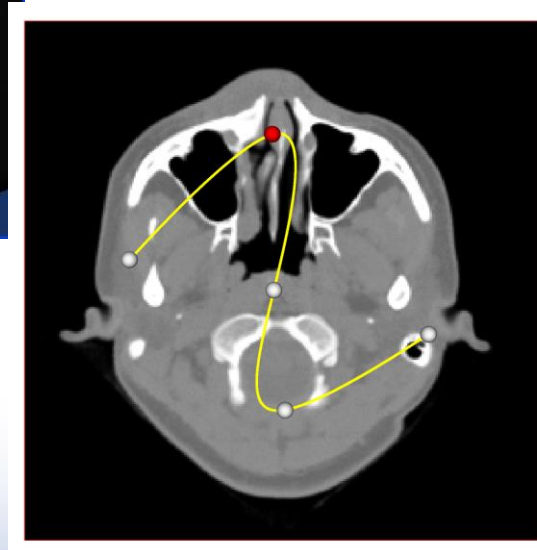
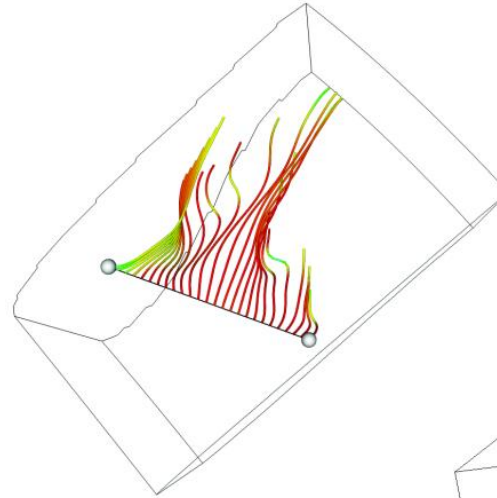
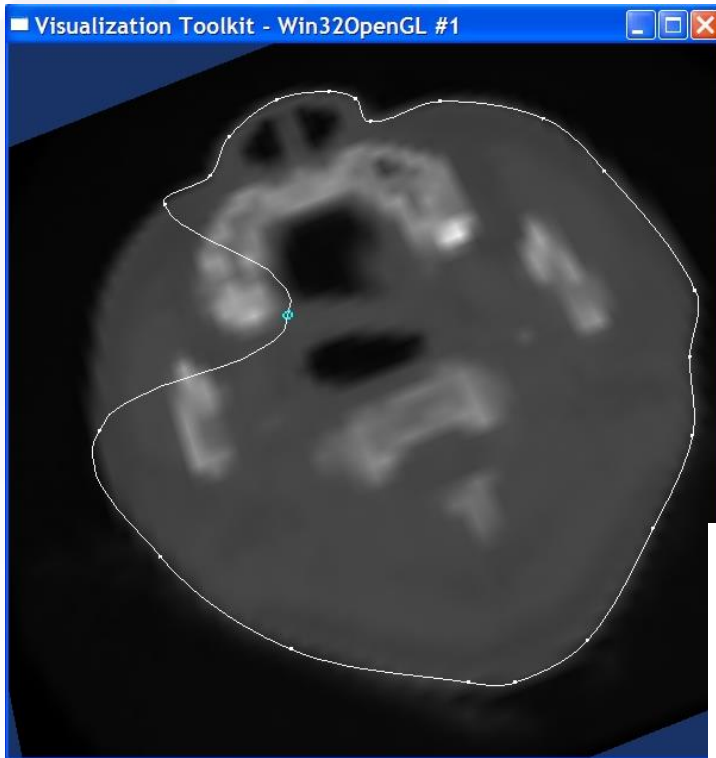




# 2D: Graphs and Charts



# Interactive Widgets



# Example Code

```
#!/usr/bin/env python

import vtk

# Load an STL File
reader = vtk.vtkSTLReader()
reader.SetFileName("myfile.stl")

# Visualization Pipeline
mapper = vtk.vtkPolyDataMapper()
mapper.SetInputConnection(reader.GetOutputPort())

actor = vtk.vtkActor()
actor.SetMapper(mapper)
```

```
# Create a rendering window and renderer
ren = vtk.vtkRenderer()
renWin = vtk.vtkRenderWindow()
renWin.AddRenderer(ren)



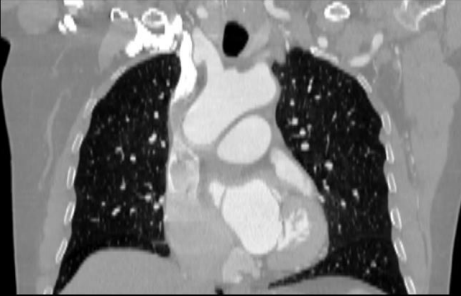
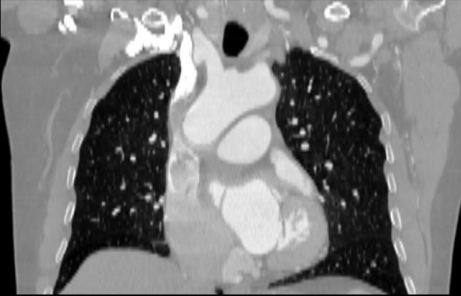

# Create a renderwindowinteractor
iren = vtk.vtkRenderWindowInteractor()
iren.SetRenderWindow(renWin)

# Assign actor to the renderer
ren.AddActor(actor)

# Enable user interface interactor
iren.Initialize()
renWin.Render()
iren.Start()
```



# Volume Rendering

<table border="1"> <thead> <tr> <th>Information</th> <th>Value</th> </tr> </thead> <tbody> <tr><td>Scope</td><td>Medical</td></tr> <tr><td>Images</td><td>92</td></tr> <tr><td>Distance Units</td><td>mm</td></tr> <tr><td>Voxel Dimensions</td><td>512 x 512 x 92 voxels</td></tr> <tr><td>Physical Dimensions</td><td>360 x 360 x 230 mm</td></tr> <tr><td>Physical Origin</td><td>-180, -180, -195.4 mm</td></tr> <tr><td>Voxel Spacing</td><td>0.703125 x 0.703125 x 2.5 mm</td></tr> <tr><td>Scaler Units</td><td>HU</td></tr> <tr><td>Scaler Range</td><td>-1024 to 3071 HU</td></tr> <tr><td>Scaler Type</td><td>short</td></tr> <tr><td>Scaler Size</td><td>2 bytes</td></tr> <tr><td>File Name</td><td>IM9</td></tr> <tr><td>Directory</td><td>C:\Users\ravila\Desktop\Desktop_DICOM</td></tr> <tr><td>Study Description</td><td>CT ANGIO CHEST WO AND</td></tr> <tr><td>Series Description</td><td>SSEG 75-75%</td></tr> <tr><td>Institution</td><td>University of Michigan Hospital</td></tr> <tr><td>Patient Name</td><td>CT750-HD CHEST 71 JIa</td></tr> <tr><td>Patient ID</td><td>AW248044413.774.1233589876</td></tr> <tr><td>Patient Age</td><td>71 year(s)</td></tr> <tr><td>Patient Sex</td><td>M</td></tr> <tr><td>Acquisition Date</td><td>01/14/09</td></tr> <tr><td>Acquisition Time</td><td>11:20:42</td></tr> <tr><td>Modality</td><td>CT</td></tr> <tr><td>Model Name</td><td>Discovery CT750 HD</td></tr> <tr><td>Exam</td><td>71</td></tr> <tr><td>Series</td><td>3</td></tr> <tr><td>mA</td><td>438</td></tr> <tr><td>kVp</td><td>120</td></tr> <tr><td>Exposure Time</td><td>260 ms</td></tr> <tr><td>Gantry/Detector Tilt</td><td>0 degrees</td></tr> <tr><td>Slice Thickness</td><td>2.5 mm</td></tr> <tr><td>Convolution Kernel</td><td>STANDARD</td></tr> <tr><td>Direction Cosine</td><td>(1, 0, 0) (0, 1, 0)</td></tr> </tbody> </table>	Information	Value	Scope	Medical	Images	92	Distance Units	mm	Voxel Dimensions	512 x 512 x 92 voxels	Physical Dimensions	360 x 360 x 230 mm	Physical Origin	-180, -180, -195.4 mm	Voxel Spacing	0.703125 x 0.703125 x 2.5 mm	Scaler Units	HU	Scaler Range	-1024 to 3071 HU	Scaler Type	short	Scaler Size	2 bytes	File Name	IM9	Directory	C:\Users\ravila\Desktop\Desktop_DICOM	Study Description	CT ANGIO CHEST WO AND	Series Description	SSEG 75-75%	Institution	University of Michigan Hospital	Patient Name	CT750-HD CHEST 71 JIa	Patient ID	AW248044413.774.1233589876	Patient Age	71 year(s)	Patient Sex	M	Acquisition Date	01/14/09	Acquisition Time	11:20:42	Modality	CT	Model Name	Discovery CT750 HD	Exam	71	Series	3	mA	438	kVp	120	Exposure Time	260 ms	Gantry/Detector Tilt	0 degrees	Slice Thickness	2.5 mm	Convolution Kernel	STANDARD	Direction Cosine	(1, 0, 0) (0, 1, 0)	<p>Volume CT GE MEDICAL SYSTEMS Discovery CT750 HD Exam: 71 Series: 3 (SSEG 75-75%)</p> <p>University of Michigan Hospital CT750-HD CHEST 71 JIa ID: AW248044413.774.1233589876 71 year(s) M 01/14/09 11:20:42</p>  <p>mA: 438 kVp: 120 Thick: 2.5 mm Kernel: STANDARD VolView 3.4</p>	<p>Axial CT GE MEDICAL SYSTEMS Discovery CT750 HD Exam: 71 Series: 3 (SSEG 75-75%) Imager: 30 / 92 -104.4 mm</p>  <p>University of Michigan Hospital CT750-HD CHEST 71 JIa ID: AW248044413.774.1233589876 71 year(s) M 01/14/09 11:20:42</p> <p>WW/WL: 1554 / -128</p>
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<p>Coronal CT GE MEDICAL SYSTEMS Discovery CT750 HD Exam: 71 Series: 3 (SSEG 75-75%) Image: 256 / 512 -0.703125 mm</p> <p>University of Michigan Hospital CT750-HD CHEST 71 JIa ID: AW248044413.774.1233589876 71 year(s) M 01/14/09 11:20:42</p>  <p>mA: 438 kVp: 120 Thick: 2.5 mm Kernel: STANDARD VolView 3.4</p>	<p>Coronal CT GE MEDICAL SYSTEMS Discovery CT750 HD Exam: 71 Series: 3 (SSEG 75-75%) Image: 256 / 512 -0.703125 mm</p> <p>University of Michigan Hospital CT750-HD CHEST 71 JIa ID: AW248044413.774.1233589876 71 year(s) M 01/14/09 11:20:42</p>  <p>WW/WL: 1554 / -128</p>	<p>Sagittal CT GE MEDICAL SYSTEMS Discovery CT750 HD Exam: 71 Series: 3 (SSEG 75-75%) Image: 256 / 512 -0.703125 mm</p>  <p>University of Michigan Hospital CT750-HD CHEST 71 JIa ID: AW248044413.774.1233589876 71 year(s) M 01/14/09 11:20:42</p> <p>WW/WL: 1554 / -128</p>																																																																				



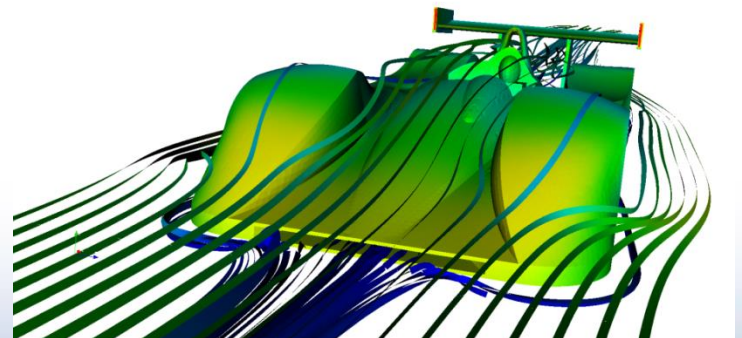
# LARGE DATA VISUALIZATION





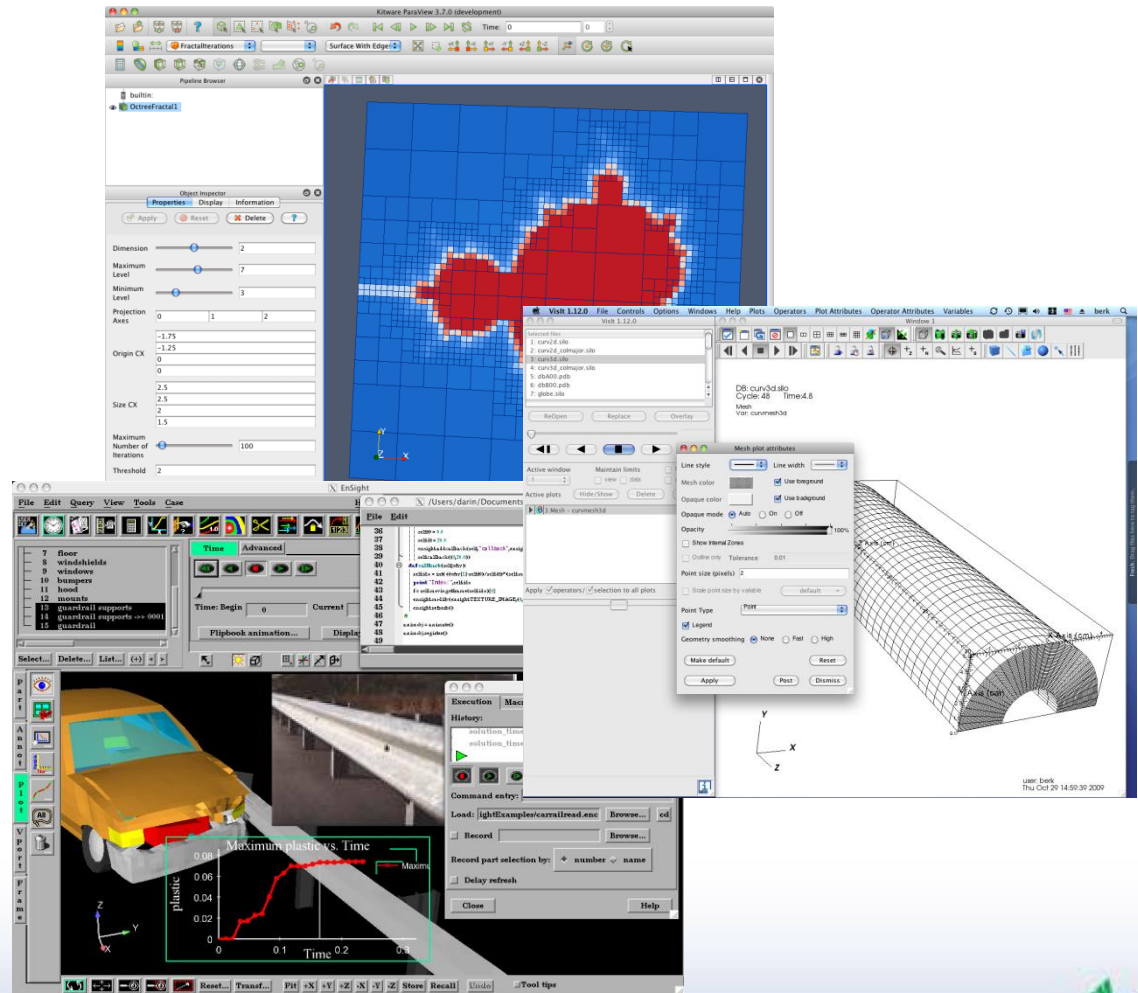
# ParaView

- [www.paraview.org](http://www.paraview.org)
- OpenSource (BSD)
- Based on VTK
- C++/Qt
- Cross-platform: Linux, Mac, Windows
- Python support
- Very active community (HPC Wire Award)
- Multi-core support (MPI)
- Co-processing (in-situ)
- More than 50 data readers



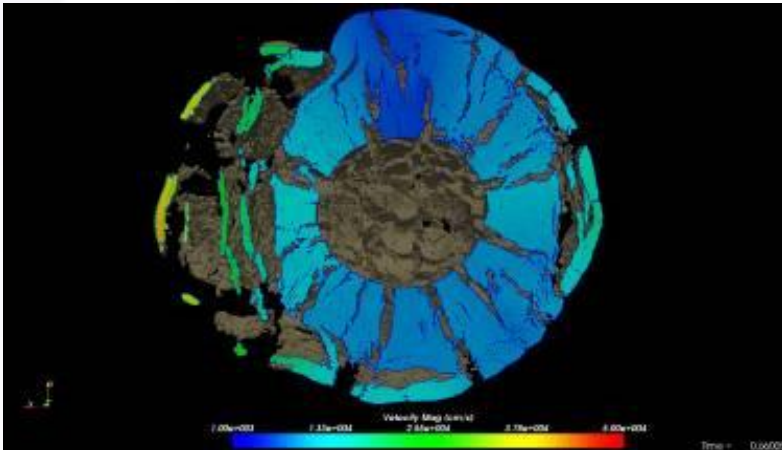
# General Purpose Tools

- EnSight
- ParaView
- VisIt
- FieldView
- TecPlot
- ...

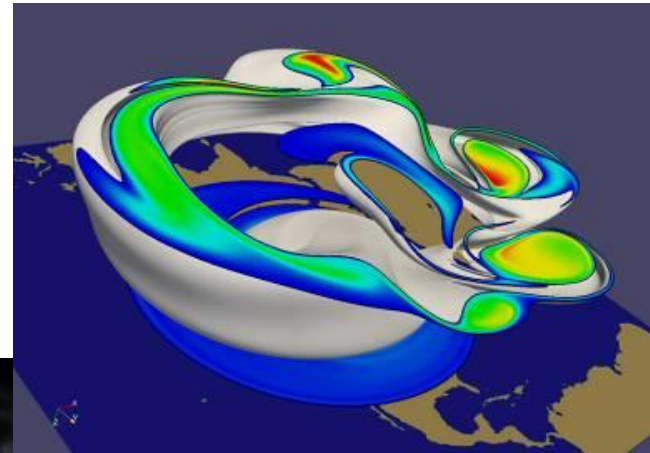


# ParaView

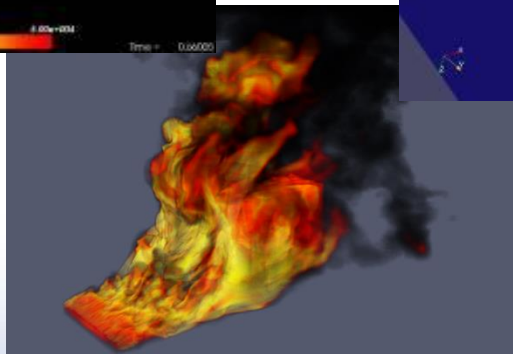
- An application and an architecture to visualize and analyze massive datasets
- A turn-key visualization application



1 billion cell asteroid  
detonation simulation



½ billion cell  
weather simulation



Fire simulation





Pipeline Browser

- builtin:
  - motorBike.foam
  - Calculator3
  - Threshold13
  - Threshold14
  - motorBike.foam

Properties

Apply Reset Delete ?

File Name: benFOAM/motorBike/motorBike.foam

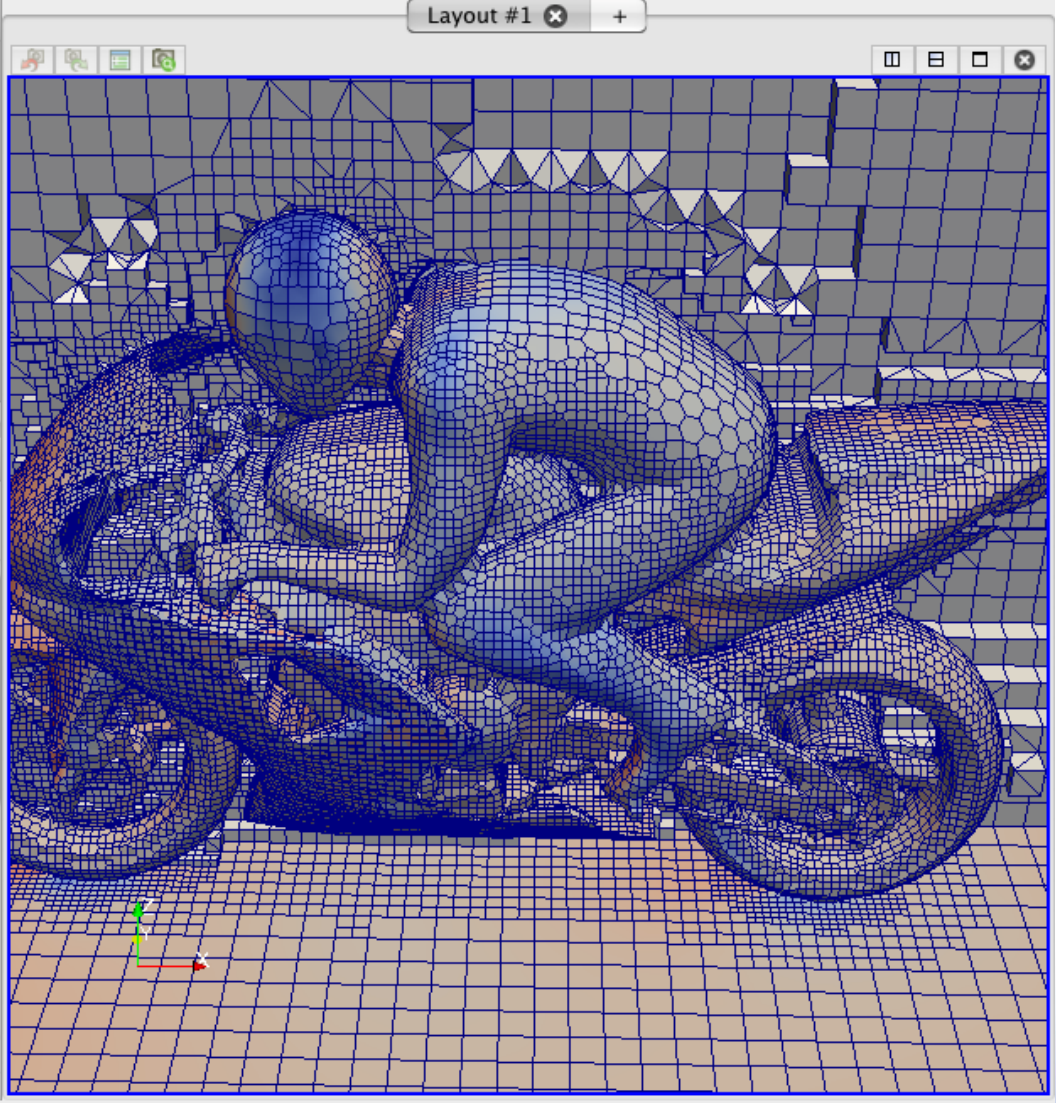
Case Type: Reconstructed Case

Create cell-to-point filtered data

Add dimensional units to array names

Mesh Regions

- internalMesh
- frontAndBack
- inlet
- outlet
- lowerWall
- upperWall
- motorBike\_frt-fairing:001%1
- motorBike\_windshield:002%2
- motorBike\_rr-wh-rim:005%5
- motorBike\_rr-wh-rim:010%10



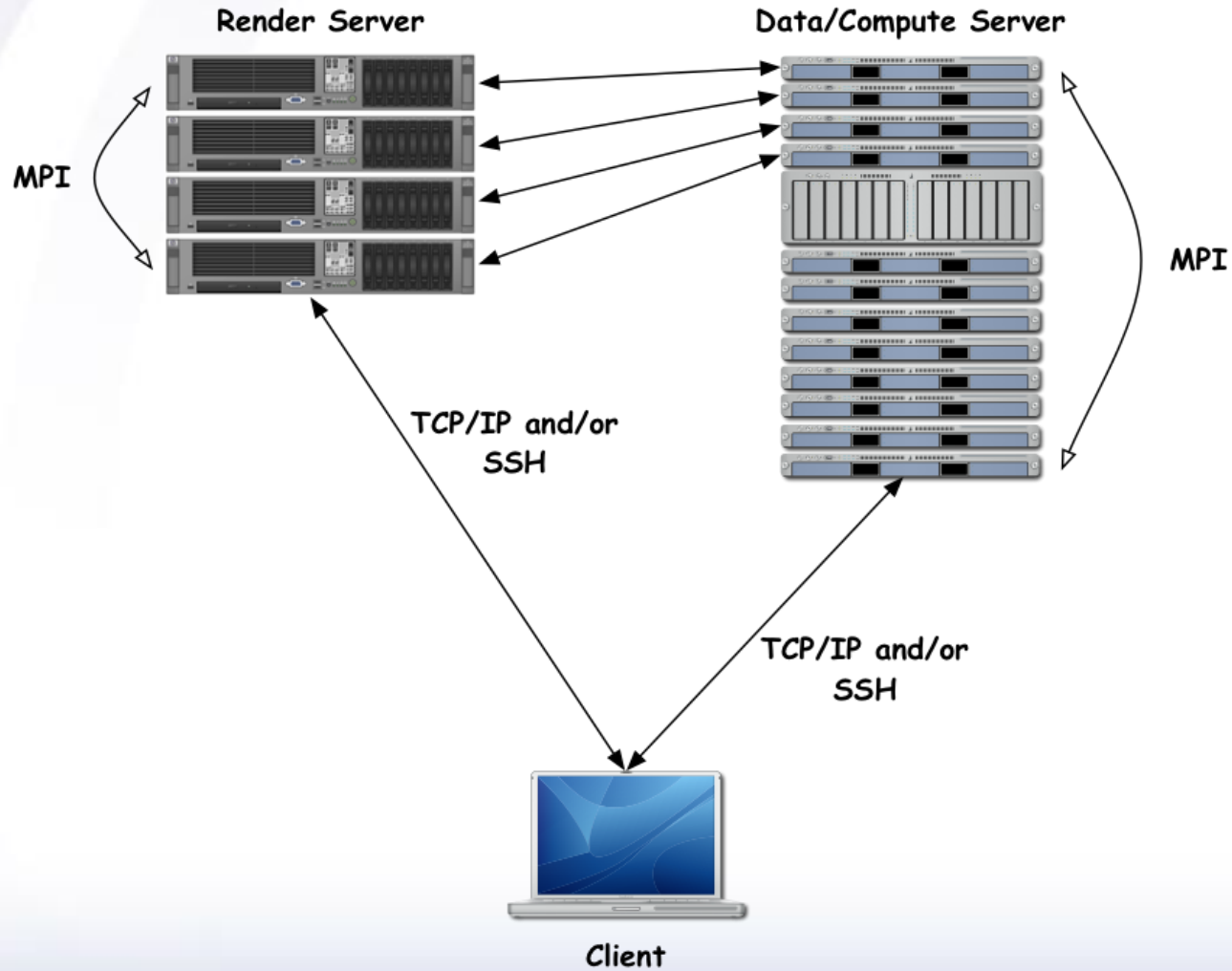
# ParaView is a Framework

- ParaView **extends VTK** to provide:
  - Client-server computing
  - State management
  - Python modules
  - Application/GUI framework
- ParaView framework can be used to **develop other applications**
- ParaView can be **embedded in other applications** and frameworks



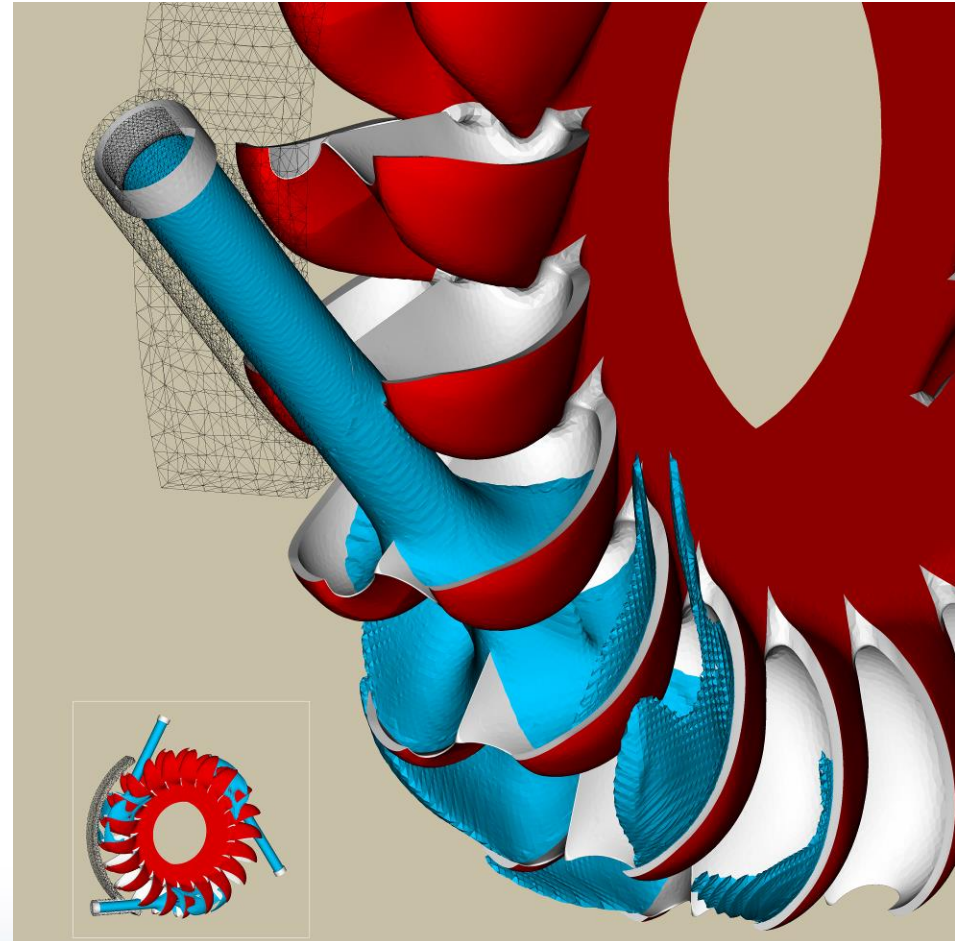
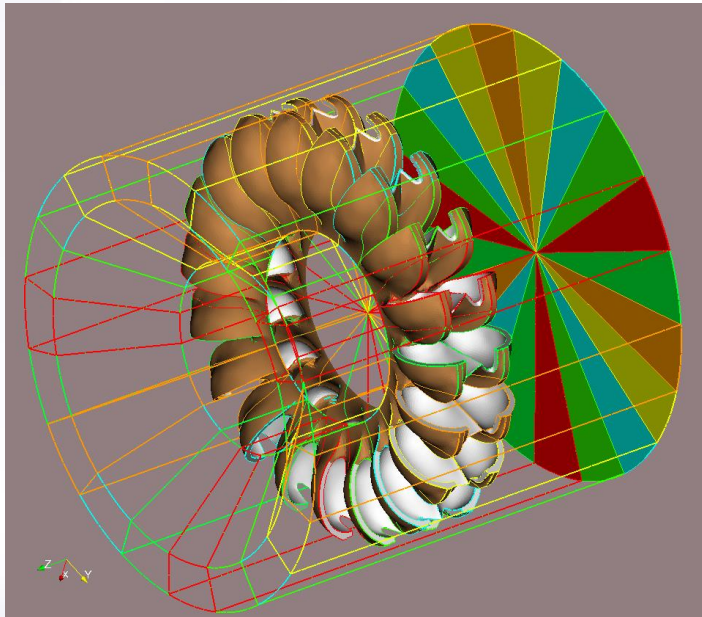


# ParaView Architecture



# Large Data - Unstructured

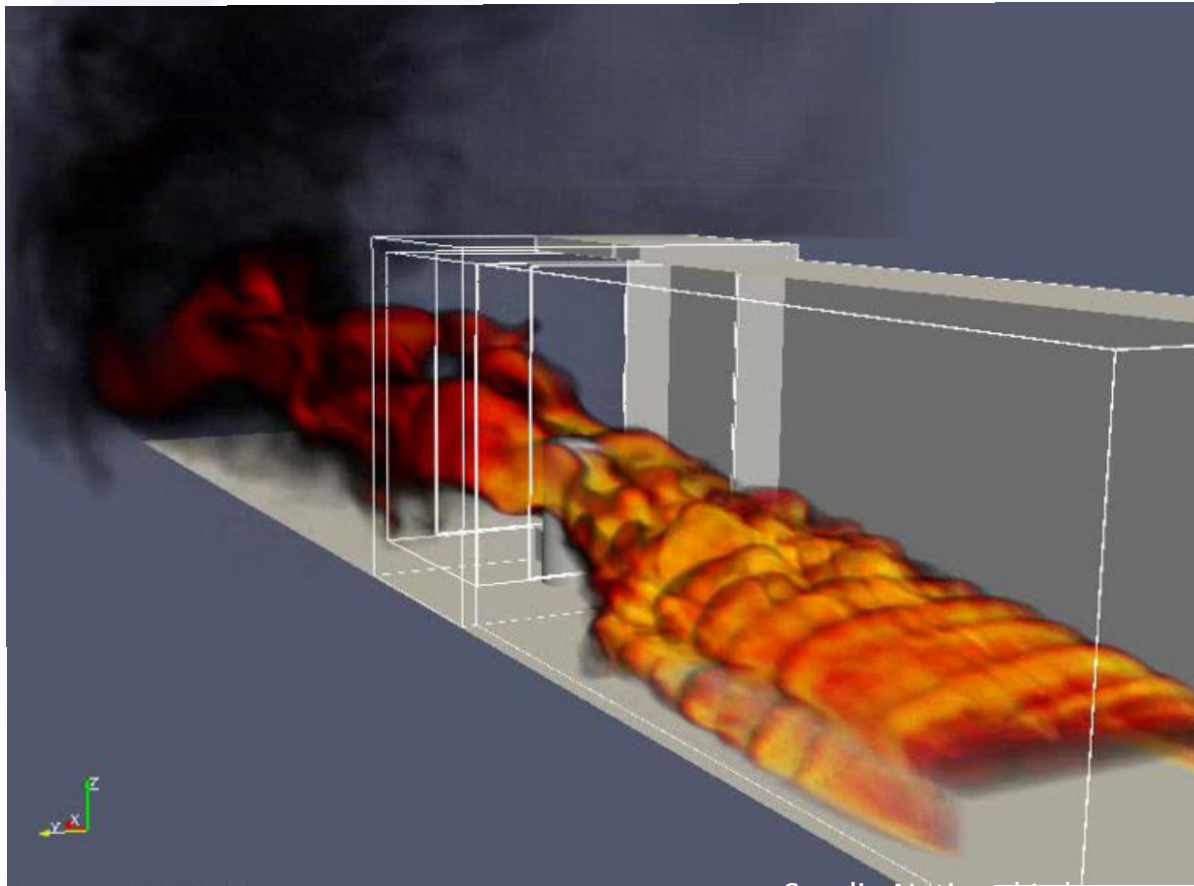
- CFD simulation
- 20-30 million elements
- Load balancing



source: Swiss supercomputing center



# Large Data - Unstructured

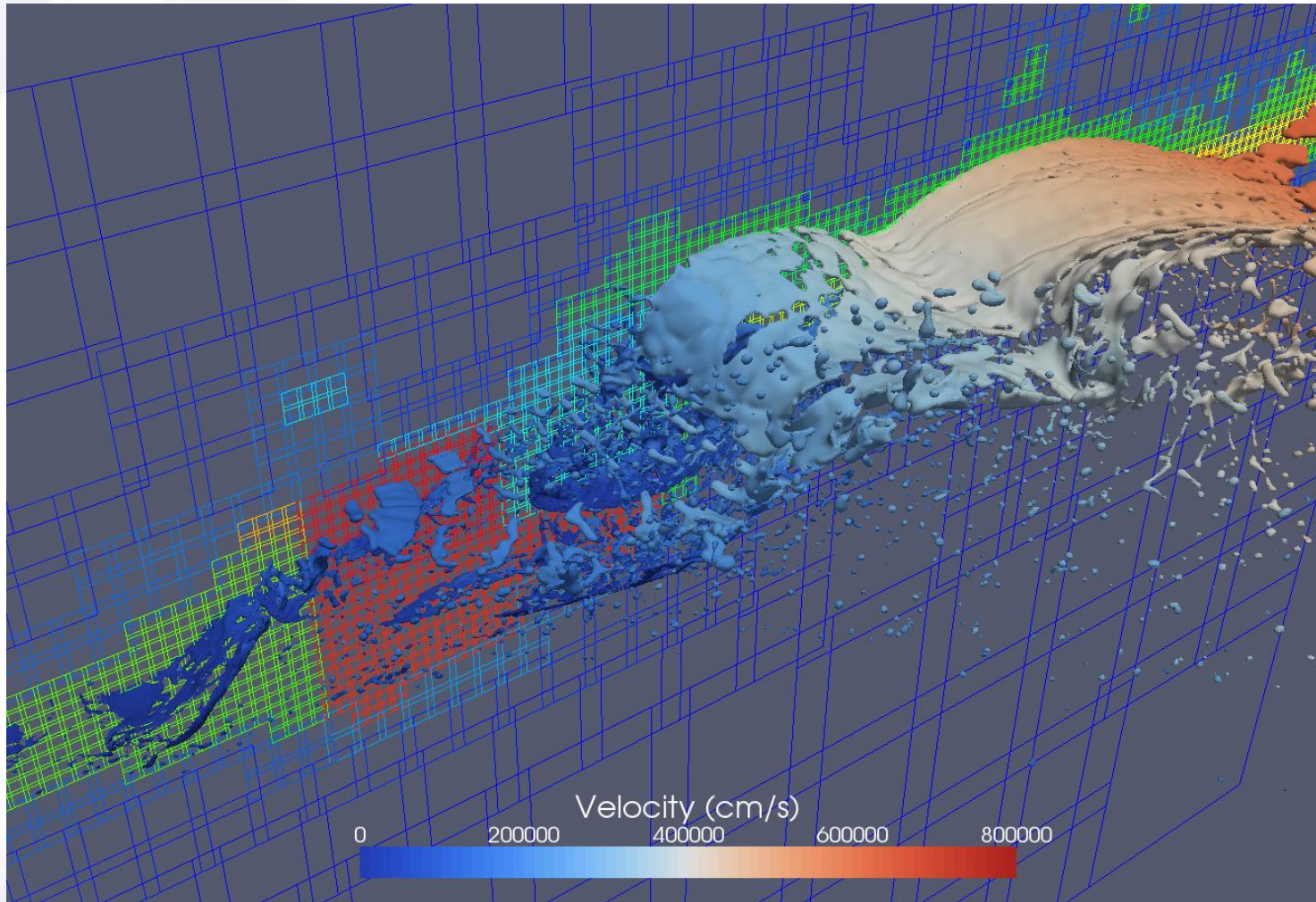


- Fire simulation
- 150 million elements

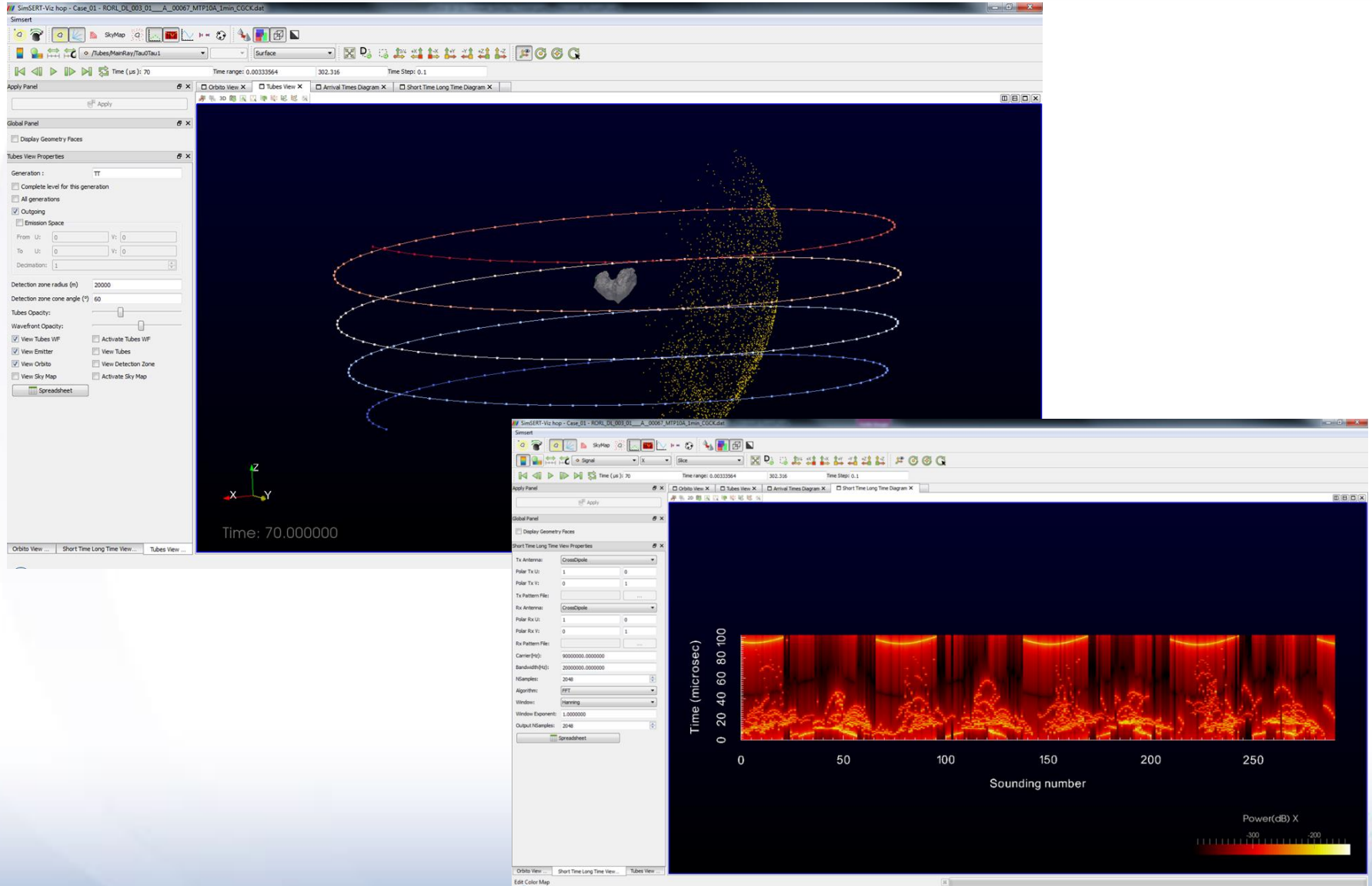




# Large-scale AMR

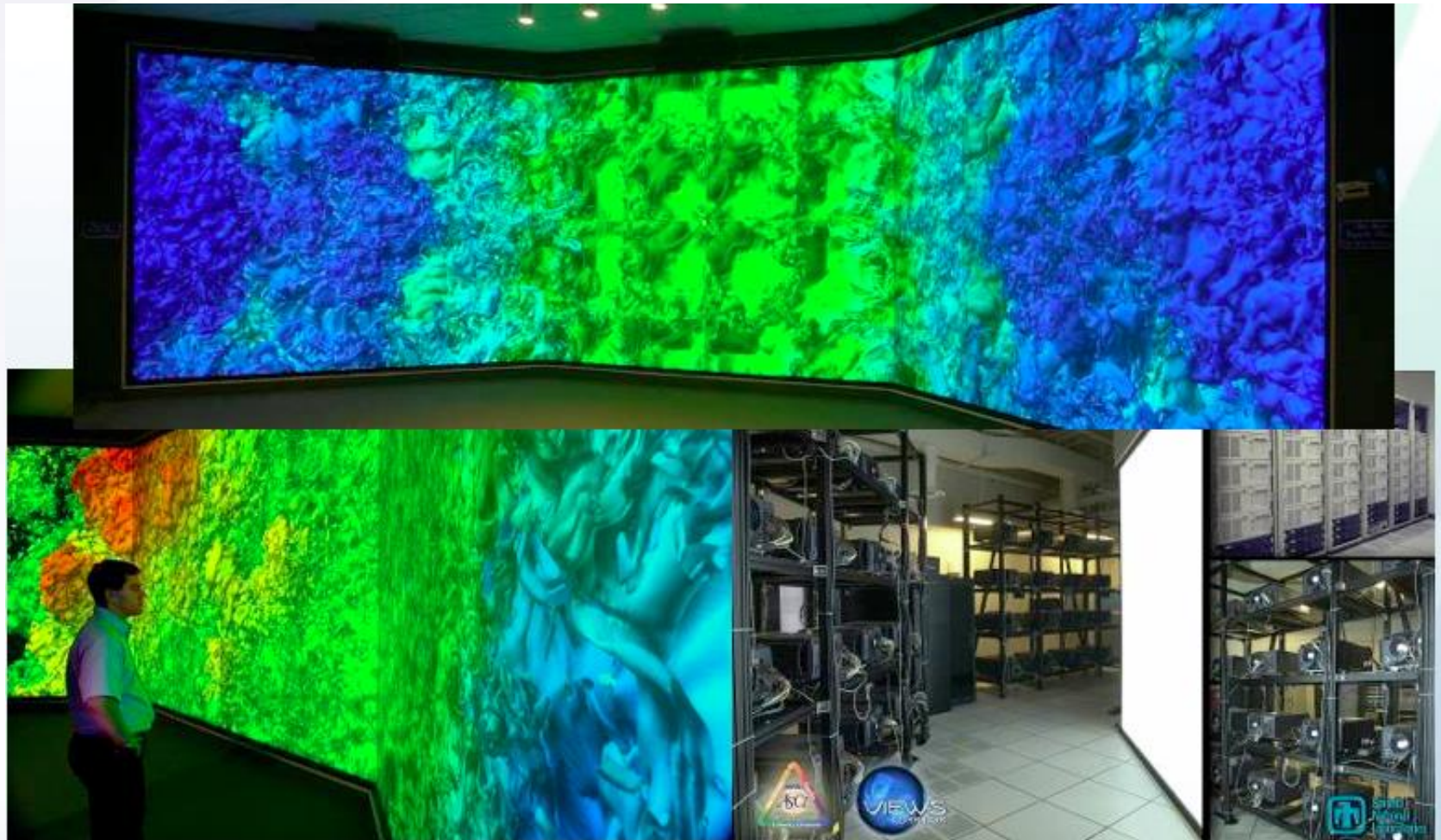


# ESA - Rosetta





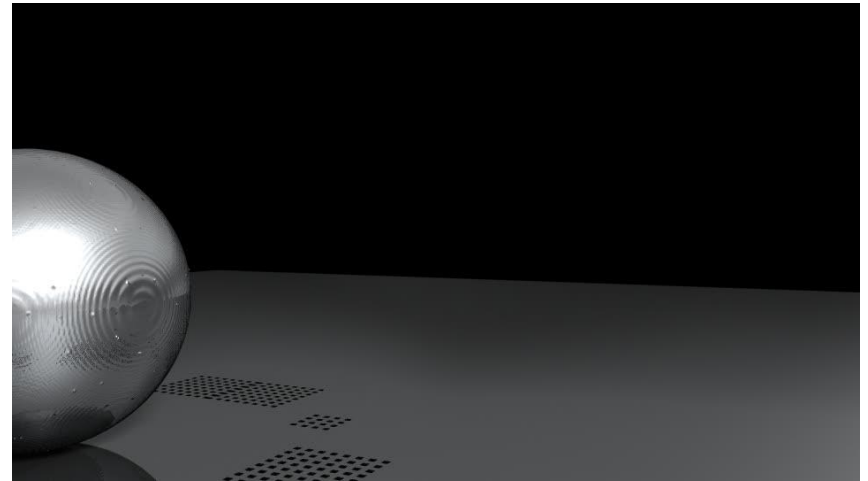
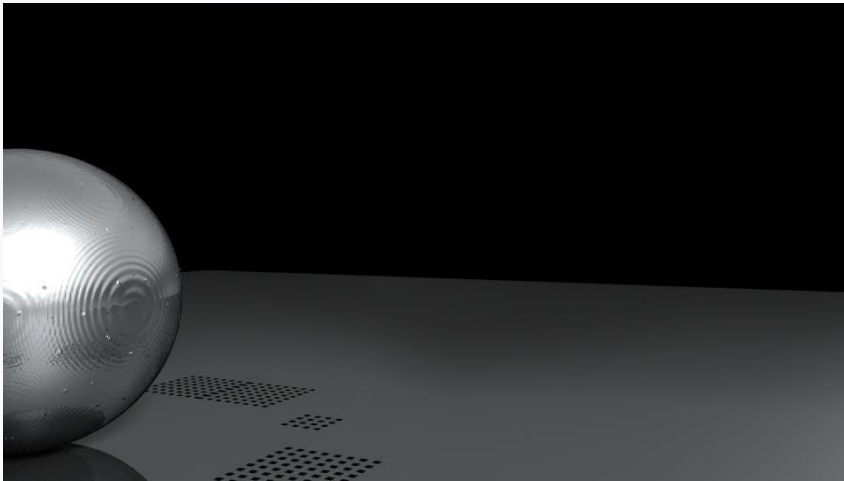
# ParaView in Use: Immersive Visualization



# In-Situ : Access to More/Richer Data

*Post-Processing*  
*(every 100 time steps)*

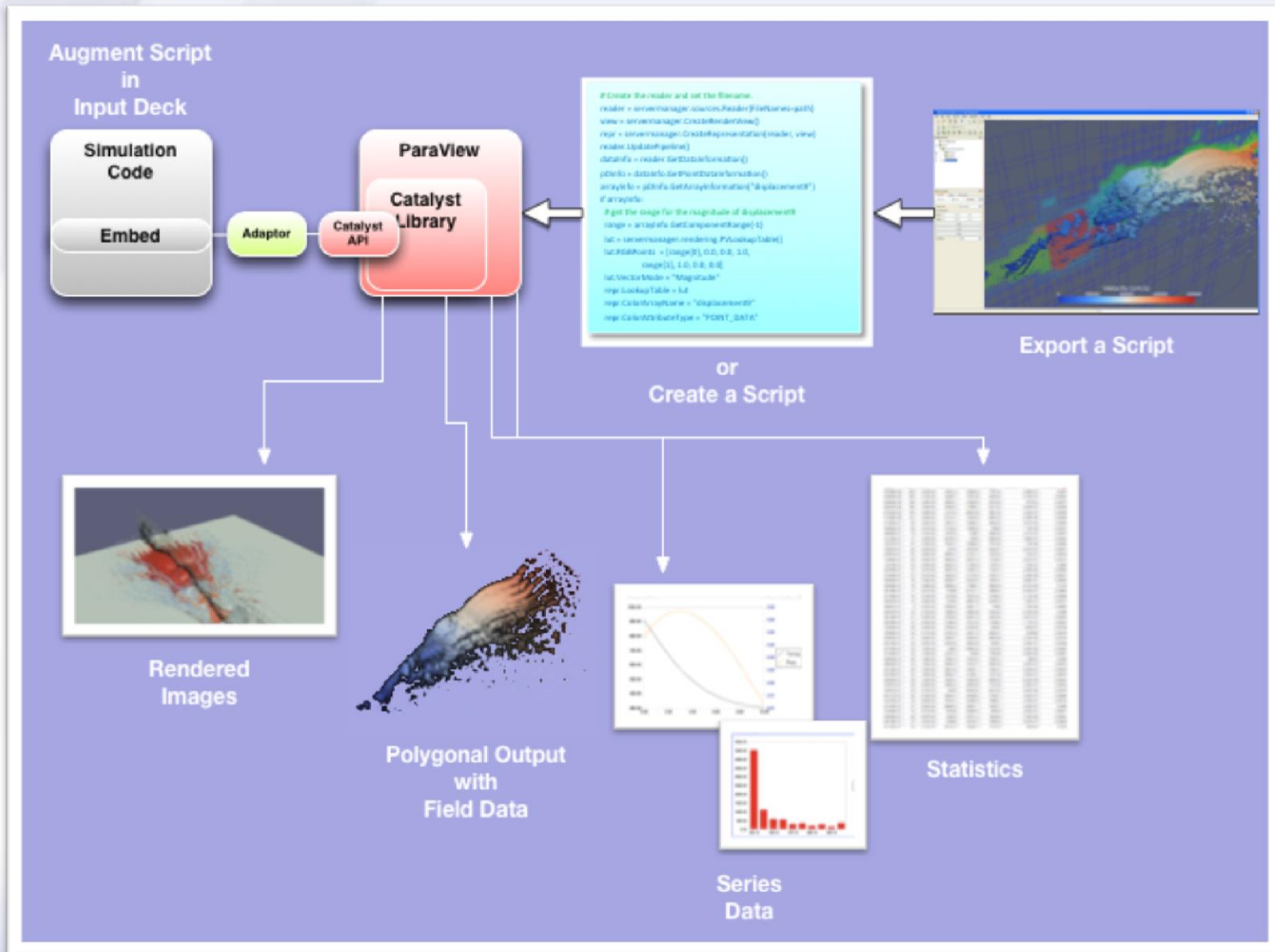
*In-situ*  
*(every time step)*



*Note: Reflections and shadows added in post-processing*



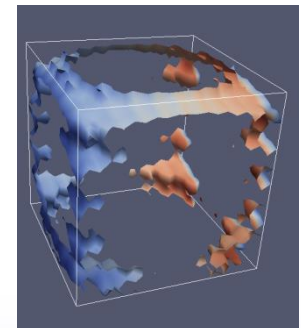
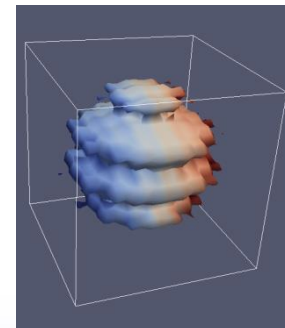
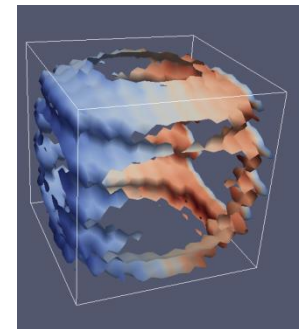
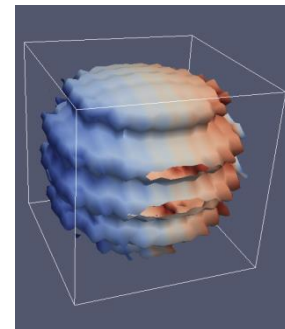

# Co-Processing/InSitu with ParaView Catalyst



```
andor:simulation ./run.sh --parameter1=1 --parameter2=1.5 --parameter3=123 --output=e1/file1.dat
andor:simulation ./run.sh --parameter1=2 --parameter2=2.5 --parameter3=123 --output=e1/file2.dat
andor:simulation ./run.sh --parameter1=4 --parameter2=1.5 --parameter3=123 --output=e1/file3.dat
andor:simulation ...
andor:simulation ./run.sh --parameter1=1 --parameter2=1.5 --parameter3=123 --output=e2/file1.dat
andor:simulation ./run.sh --parameter1=2 --parameter2=2.5 --parameter3=123 --output=e2/file2.dat
andor:simulation ./run.sh --parameter1=2 --parameter2=2.5 --parameter3=123 --output=e2/file3.dat
andor:simulation ...
andor:simulation □
```



```
1 try: paraview.simple
2 except: from paraview.simple import *
3
4 for idx in range(1, 100):
5     reader = Read( FileName='e%d.dat' % idx )
6
7     DataRepresentation3 = Show()
8
9     Contour2 = Contour()
10    Contour2.ContourBy = ['POINTS', 'Density']
11    Contour2.Isosurfaces = [2.5850499793887138]
12
13    DataRepresentation4 = Show()
14
15    Render()
16
17    SaveImage("contour%d.png" % idx)
```

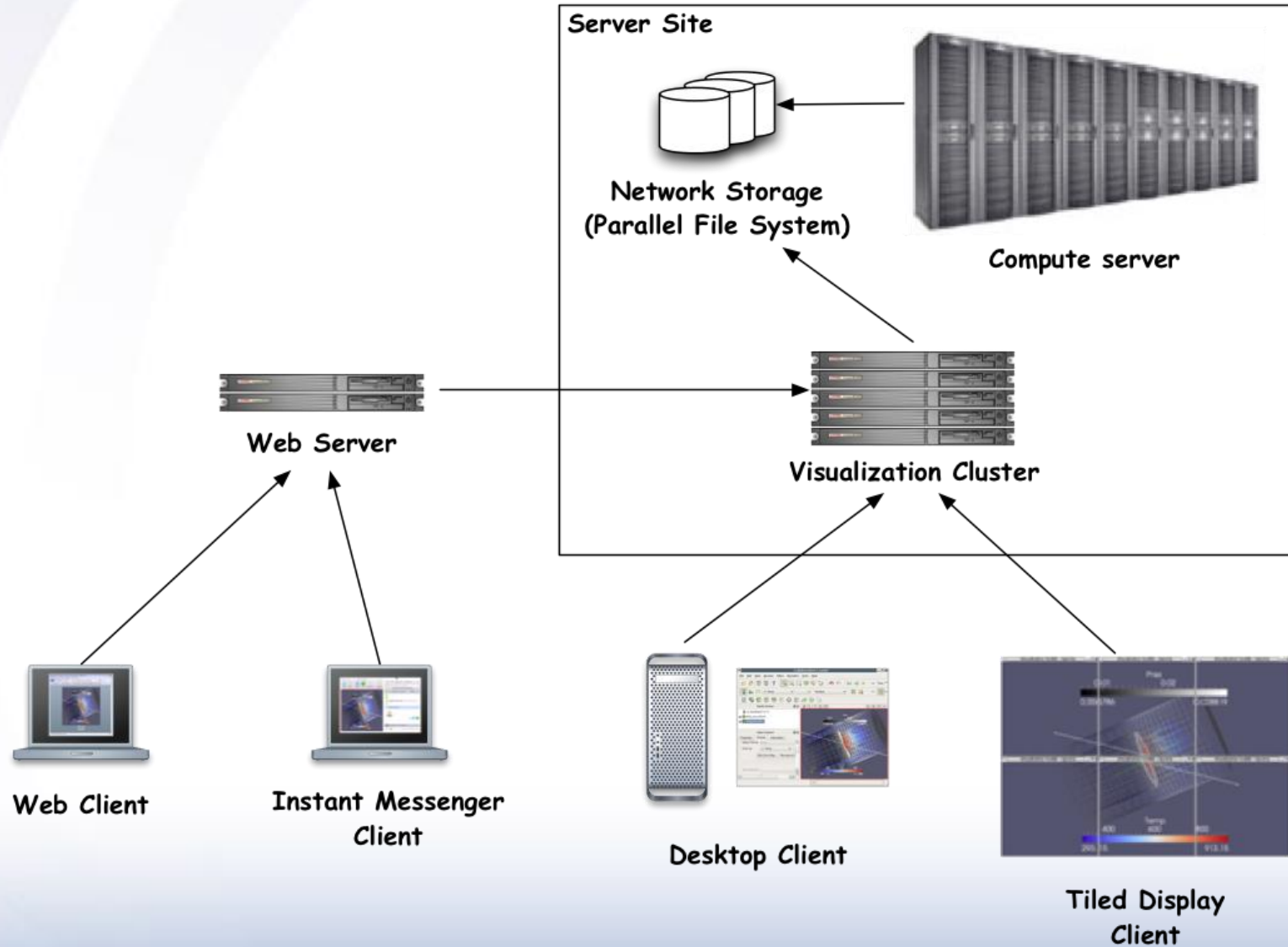


# OTHER VISUALIZATION TOOLS



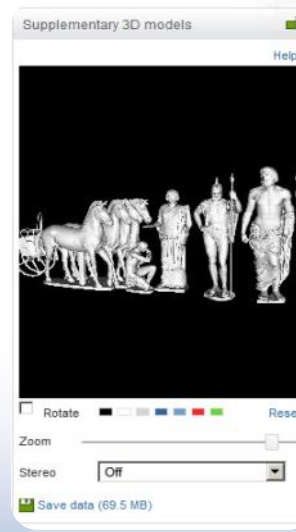
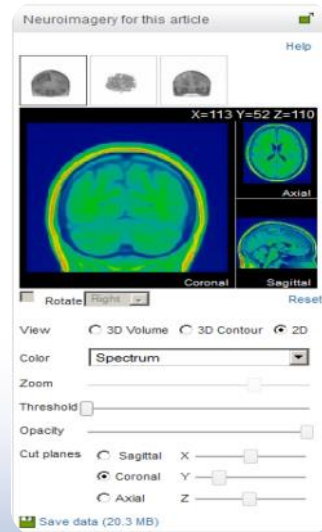
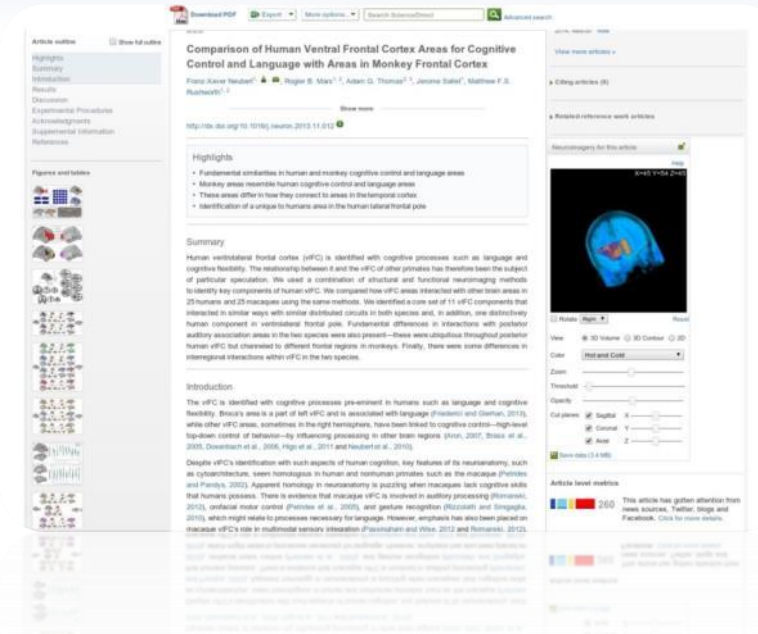


# ParaViewWeb - Collaboration

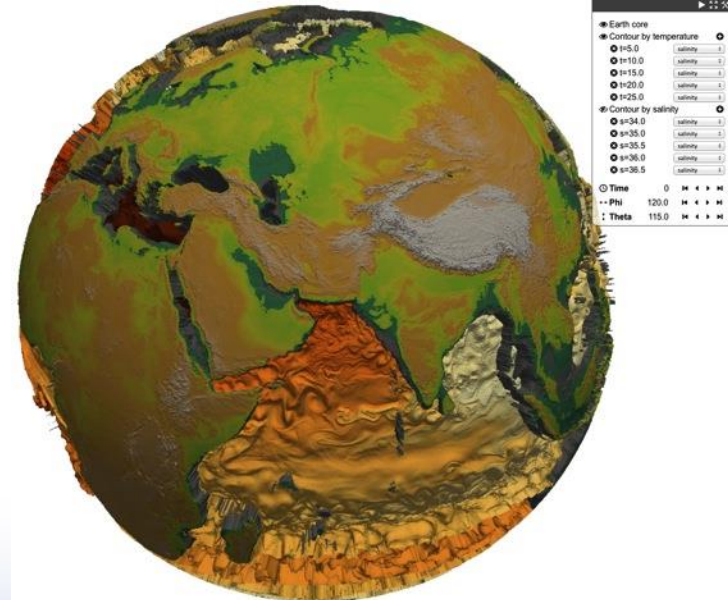
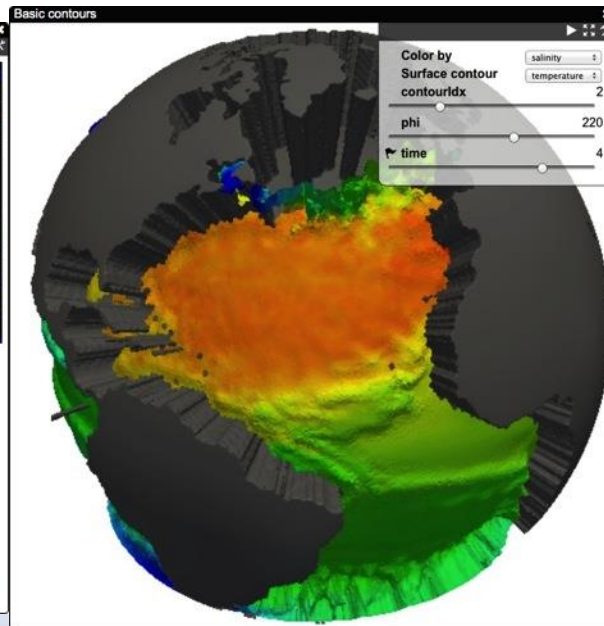
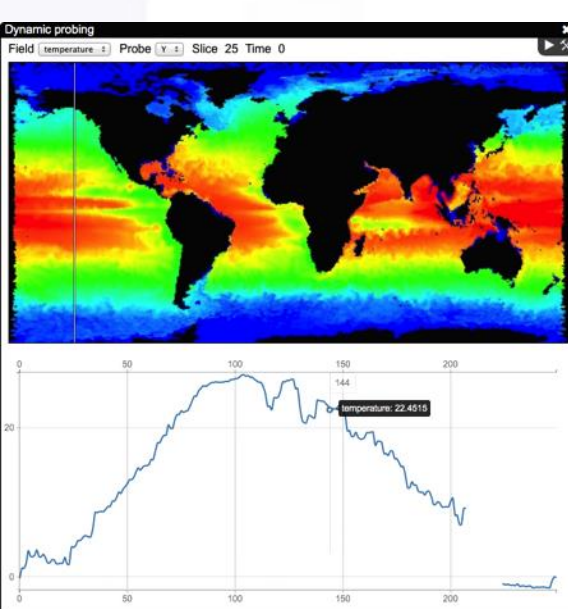
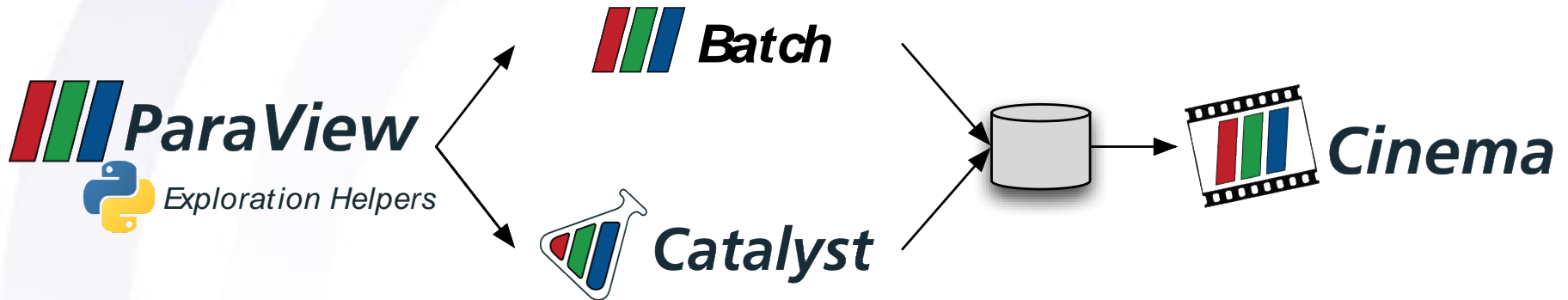


# Web Visualization – vtkWeb/ParaViewWeb

- <http://www.webviz.org>
- No plugin
- Works on all devices and browsers
- Instant visualization (fast loading)
- Fully interactive visualization



# ParaView - Cinema



# Mobile Visualization: VES/VTK

Mobile Visualization Apps

Kiwi iOS

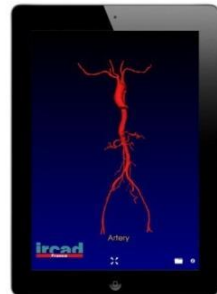
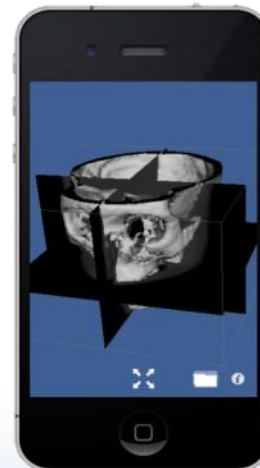
Kiwi Android

Kiwi

VTK

VES

Open GL  
ES 2.0



Kitware **ircad**

Kitware **ircad**

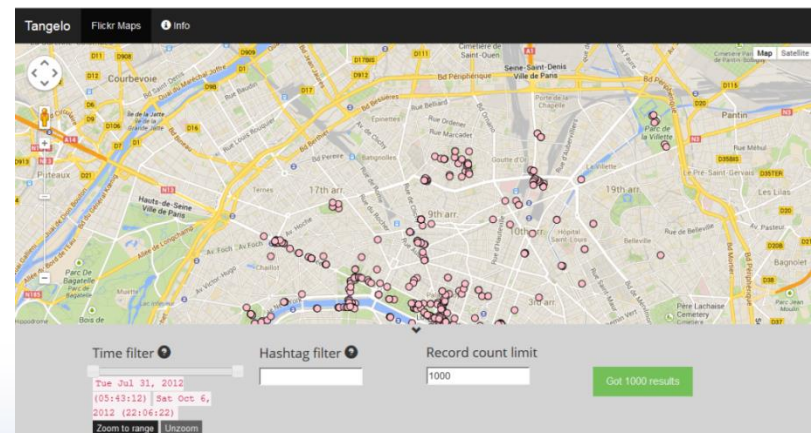
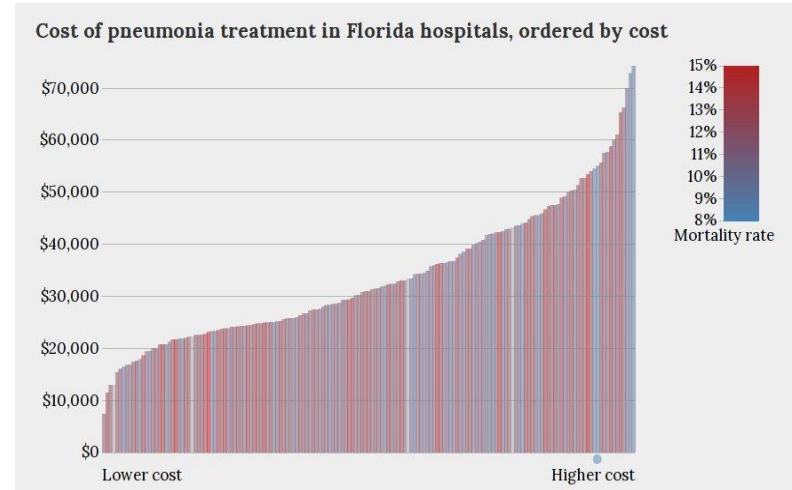




# Tangelo



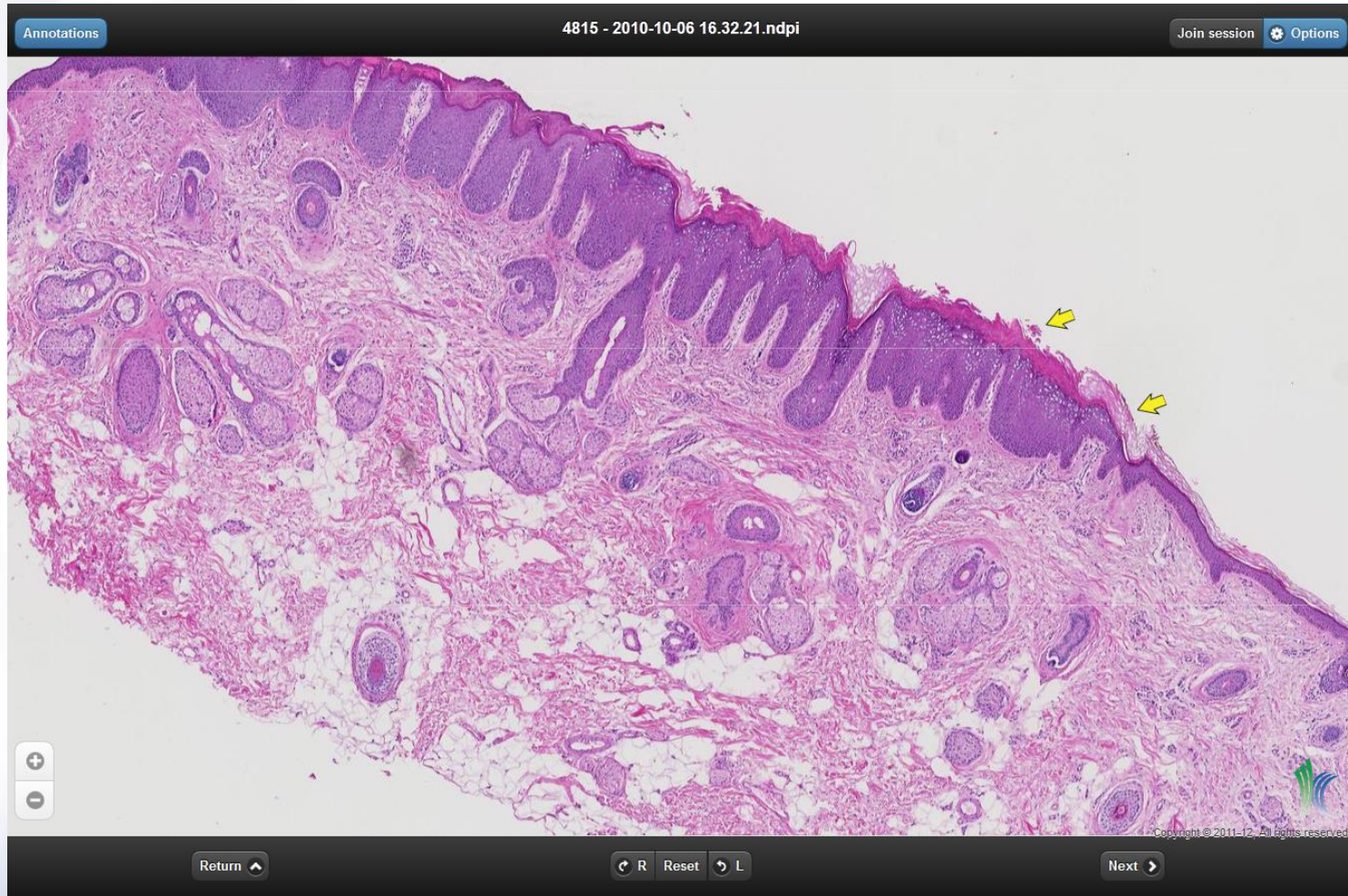
- <http://tangelo.kitware.com>
- Web framework
- HTML5 web architecture
- Packages several other frameworks too
  - Bootstrap, D3, Vega, MongoDB
- Facilitates development & deployment of web apps





# Visualization of large 2D images

- Digital Pathology: <https://slide-atlas.org/>



# Open Chemistry

The image displays the Avogadro software interface. The main window, titled "nanotube.xyz - Avogadro", shows a 3D model of a carbon nanotube with a rainbow color gradient. The interface includes a "Tools" menu, an "AutoOptimization" panel with settings for Force Field (UFF), Steps per Update (4), and Algorithm (Steepest Descent), and a "Display Types" panel with options like Ball and Stick, Dipole, Hydrogen Bond, Label, Orbitals, and Overlay. A "Messages" button is visible at the bottom.

An inset window shows a molecular orbital visualization of a molecule, with a table of atom coordinates (X, Y, Z) displayed below it. The table contains the following data:

	X	Y	Z
Atom 1	-0.06439	-0.00283	0.37013
Atom 2	0.13961	1.39417	0.64913
Atom 3	-0.67239	2.08717	-0.22287
Atom 4	-1.67339	1.43917	-0.94687
Atom 5	-1.85639	0.08017	-0.79887
Atom 6	-1.05539	-0.64083	0.06613
Atom 7	-1.25989	-2.11911	0.21733
Atom 8	0.50830	-0.58072	1.48609
Atom 9	0.93945	1.85054	1.22109
Atom 10	-0.51997	1.17194	-0.33841
Atom 11	-2.31487	2.01159	-1.81544
Atom 12	-2.64764	-0.43228	-1.37130

<http://www.openchemistry.org/>



# VTKWeb and Open Chemistry



InChIKey	IZRSVHMKZWKSSV-UHFFFAOYSA-N
SMILES	<chem>c1cc2ccc3c4cccc(cc4[se]c3c2o1)-c1ccc[se]1</chem>
Formula	C <sub>18</sub> H <sub>10</sub> OSe <sub>2</sub>
Molecular Mass	400.196
Energy	
Homo	-0.112
Lumo	-0.002
Gap	0.11
Total	-5543.7168293588
Calculation	
Theory	BP86
Basis	STO-6G

Download

Mass 400.196

Energy Homo -0.112

Mass 400.196

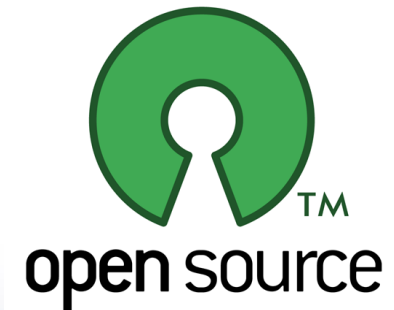
Energy Homo -0.113

<http://data.openchemistry.org/>



# Benefits of Open-Source

- **Extended support**
  - The Visualization Toolkit: ~\$140M
- **Active maintenance**
  - Community-supported
  - Training
- **Access to expertise**
- **Reduce costs**
  - Development
  - Maintenance
  - Evolution
  - No licensing fee







# Thank You!

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