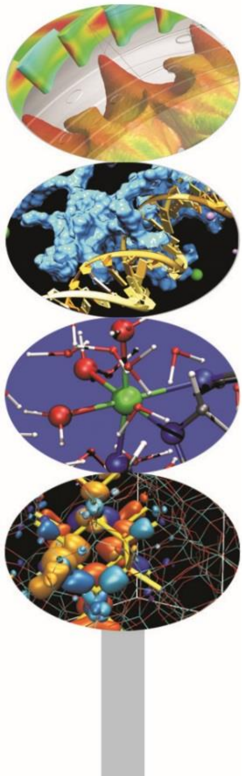
Introducing a new Client-Server framework for large CFD models



Andrea Paroni

Paolo Geremia

Stefano Valeri

Workshop "HPC enabling of OpenFOAM® for CFD applications“, Bologna, 6-8 April 2016

Outline

- Introducing HELYX®
- Motivation
- HELYX Client-Server Network Architecture
- HELYX® HPC Usage
- Live Demo
- Future Developments

Our Company

- CAE products and services
- Leverage open-source solutions
- OPENFOAM® developers since 1999
- Solution platforms:
- CFD → HELYX® / ELEMENTS
- MDO → HELYX-Adjoint / DAKOTA
- Founded UK 2009
- 5 Offices worldwide
  - UK, Germany, Italy, USA, Australia
- Resellers
  - Japan (2), Benelux, Korea, China, USA

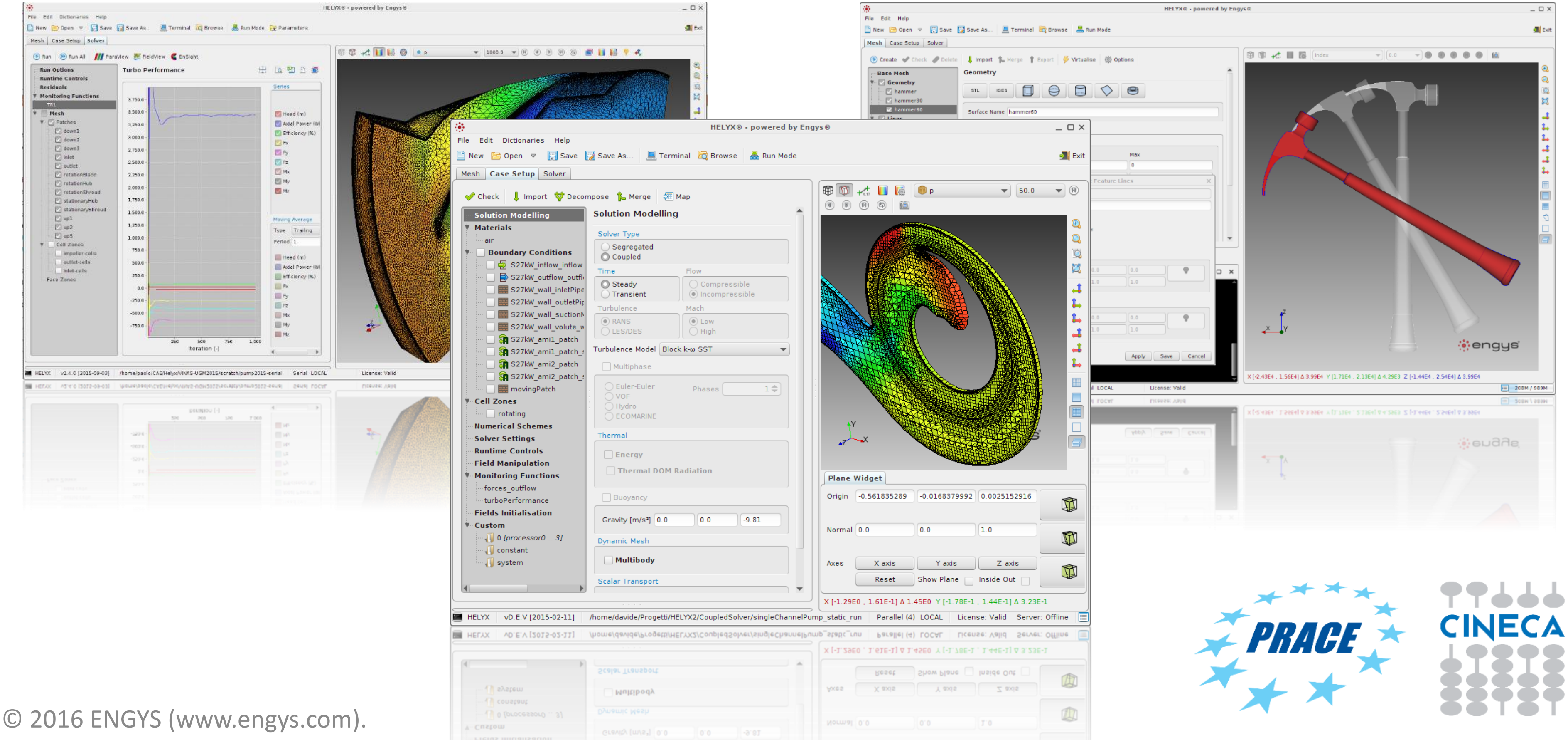
OPENFOAM® is a trademark of OPENCFD (ESI Group).

Our Company

- ENGYS has
  - 14+ years development track-record FOAM/OPENFOAM®
  - 12+ years development track-record GUI/Java
  - Extensive knowledge of OSS and commercial CAE tools
- Mission: develop a professional CFD software solution based on OSS technology derived from OPENFOAM with an easy-to-use GUI

HELYX® | Introduction

- HELYX® is a comprehensive CFD software solution for industry based on proven open-source technologies



Solution Modelling

Solver Type
○ Segregated
● Coupled

Time
● Steady
○ Transient

Flow
○ Compressible
● Incompressible

Turbulence
● RANS
○ LES/DES

Mach
● Low
○ High

Turbulence Model: Block k-ω SST

□ Multiphase
○ Euler-Euler
○ VOF
○ Hydro
○ ECOMARINE
Phases: 1

Thermal
□ Energy
□ Thermal DOM Radiation

□ Buoyancy

Gravity [m/s²]: 0.0 0.0 -9.81

Dynamic Mesh
□ Multibody

Scalar Transport

Origin: -0.561835289 -0.0168379992 0.0025152916
Normal: 0.0 0.0 1.0
Axes: X axis, Y axis, Z axis
Show Plane □ Inside Out □

X [-1.29E0 , 1.61E-1] Δ 1.45E0 Y [-1.78E-1 , 1.44E-1] Δ 3.23E-1

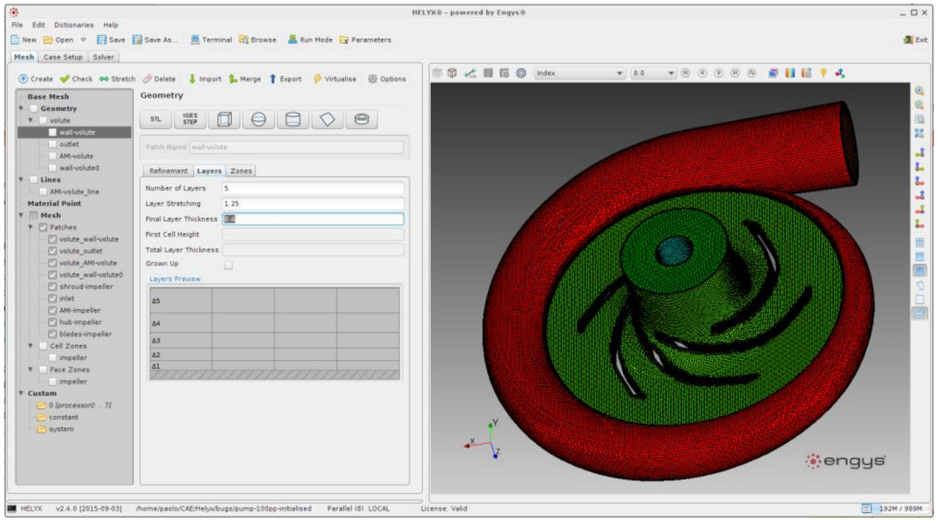
HELYX vD.E.V [2015-02-11] /home/davide/Progetti/HELYX2/CoupledSolver/singleChannelPump_static_run Parallel (4) LOCAL License: Valid Server: Offline

HELYX v2.4.0 [2015-09-03] /home/paolo/CAE/Helyx/VINAS-UGM2015/scratch/pump2015-serial Serial LOCAL License: Valid

HELYX® | Software Components

Features

- Proprietary Meshing
- Incompressible Flow
- Compressible Flow
- RANS/LES/DES
- Heat Transfer
- Multiphase
- Reacting Flows
- Passive Scalars
- Post-Processing



Patch Name: wall-volute

Number of Layers: 5

Layer Stretching: 1.25

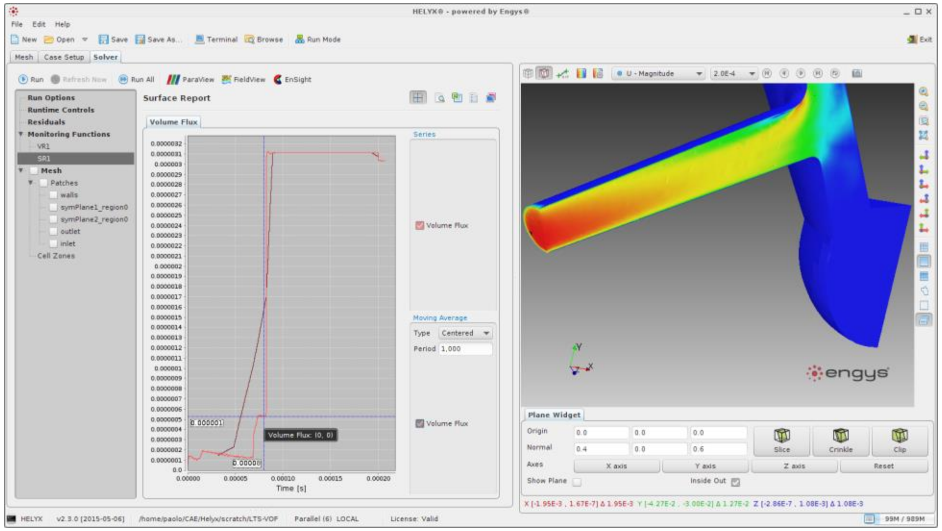
Final Layer Thickness: 0.4

First Cell Height:

Total Layer Thickness:

Grown Up: □

HELYX v2.4.0 [2015-09-03] /home/paolo/CAE/Helyx/bugs/pump-100pp-initialised Parallel (8) LOCAL License: Valid 192M / 989M



Moving Average: Type Centered, Period 1,000

Plane Widget

Origin 0.0 0.0 0.0

Normal 0.4 0.0 0.6

Show Plane □ Inside Out ☑

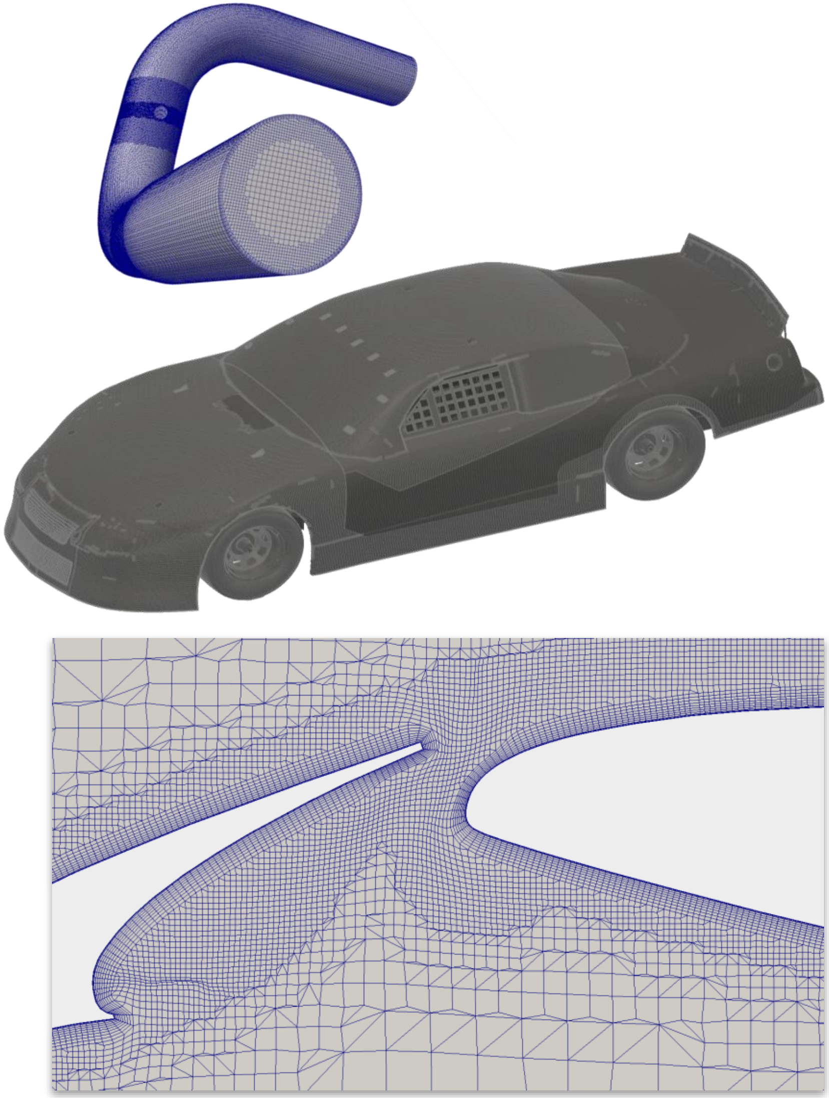
X [-1.95E-3 , 1.67E-7] Δ 1.95E-3 Y [-4.27E-2 , -3.00E-2] Δ 1.27E-2 Z [-2.86E-7 , 1.08E-3] Δ 1.08E-3

HELYX v2.3.0 [2015-05-06] /home/paolo/CAE/Helyx/scratch/LTS-VOF Parallel (6) LOCAL License: Valid 99M / 989M

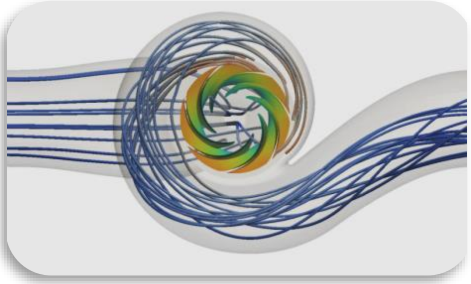
HELYX® | Software Components

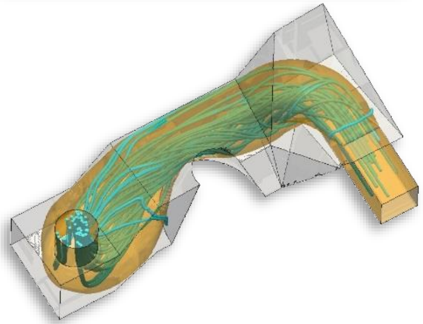
Meshing

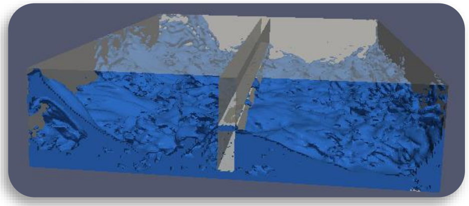
- Hexahedral mesh generator
- Created by original *snappyHexMesh* developers
- Features
  - Fully parallel
  - Commercial quality grids
  - Guarantees solver convergence
  - Integrated automatic wrapping

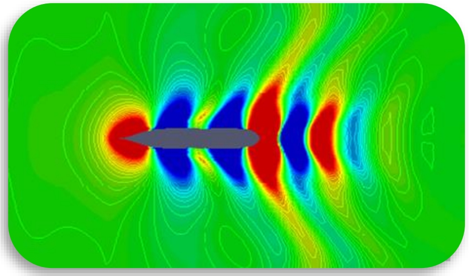


HELYX® | Software Components









Add-on Modules

- Extend capabilities beyond HELYX® feature list:
  - **Coupled** → fully implicit block coupled solvers
  - **Adjoint** → continuous CFD adjoint for topology and shape optimisation
  - **Hydro** → enhanced VOF multi-phase environment with thermal capabilities
  - **EcoMarine** → ship hull hydrodynamics

Outline

- Introducing HELYX®
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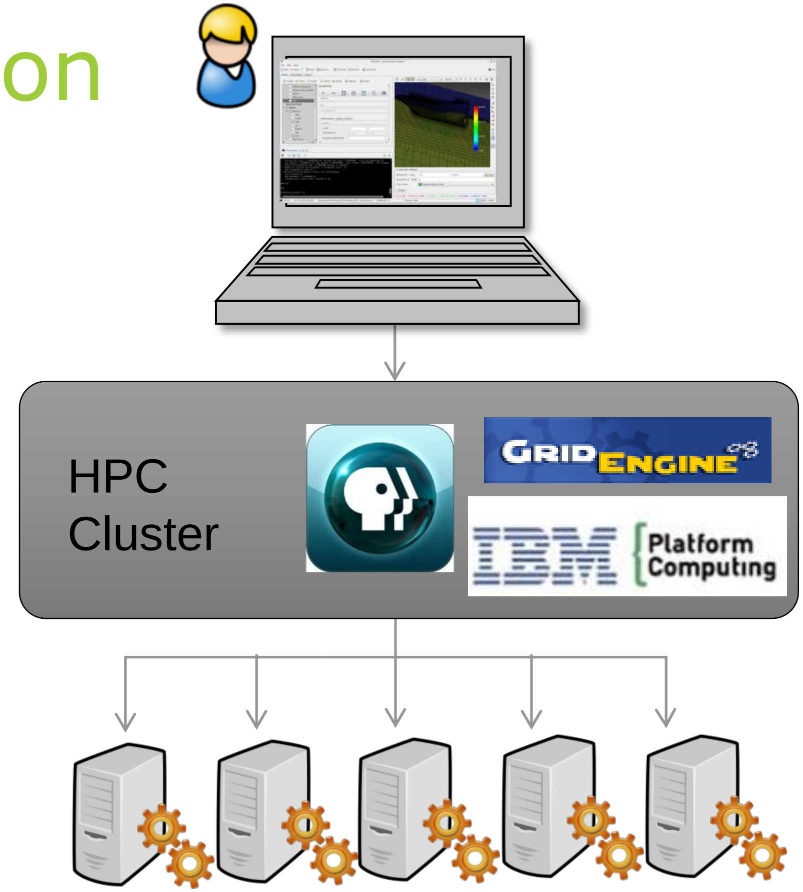
- HELYX Client-Server Network Architecture
- HELYX® HPC Usage
- Live Demo
- Future Developments

Motivation

- Current interface available in HELYX®
  - Control parallel local and remote executions
  - Shared or Distributed memory
  - Connect to any machine with a network/internet connection
  - Asynchronous client-server
  - Supports queue system for HPC clusters



Motivation

- Current interface available in HELYX®
  - Missing remote visualisation of CFD results data
  - Missing fully synchronous client/server architecture
  - Large datasets not suitable for transfer
- Solution → New HELYX Client-Server
- Development funded by FORTISSIMO EU FP7
  - Fortissimo Project Call 1: *Cloud-based simulation of pipeline components for the Oil and Gas Industry*

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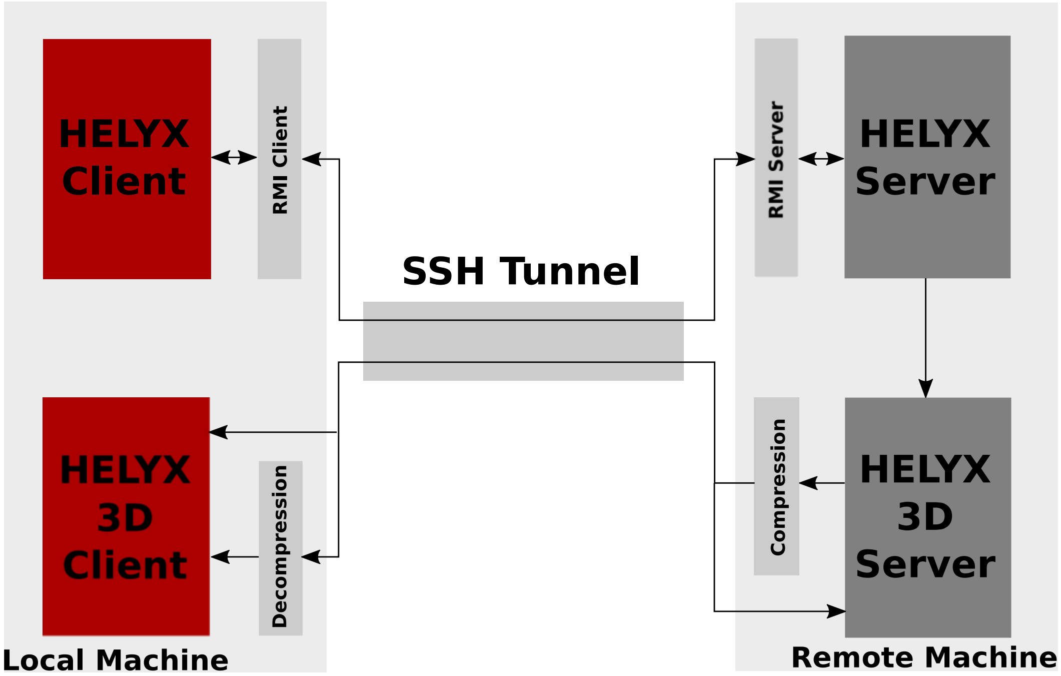
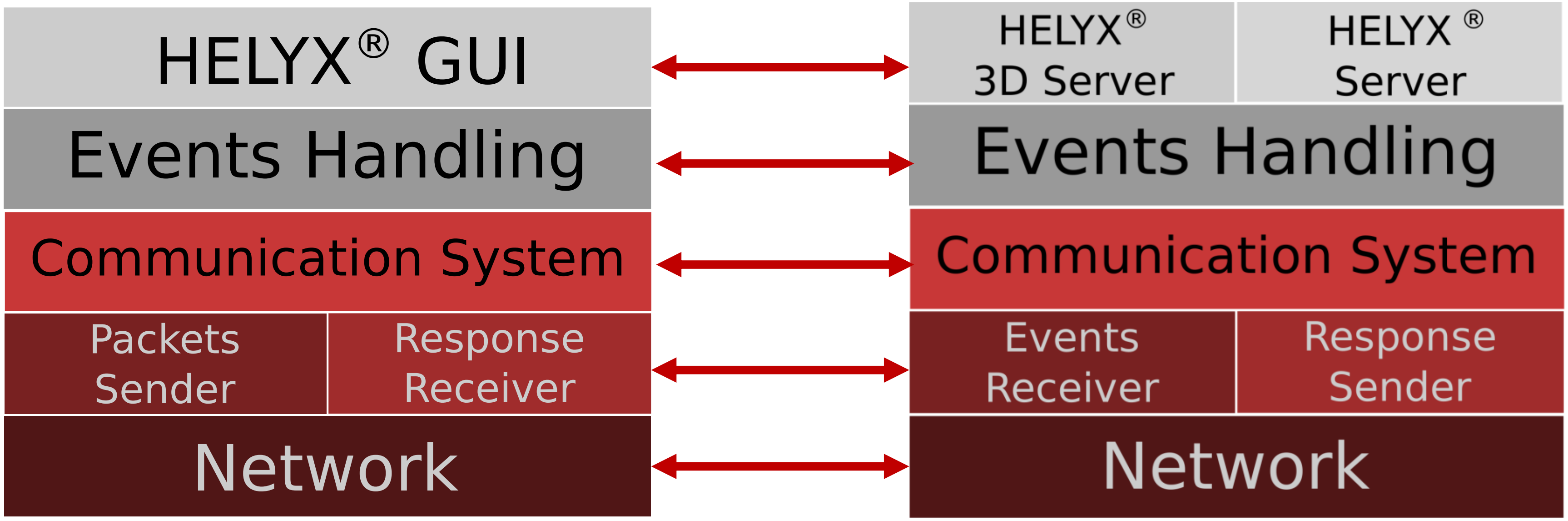
HELYX Client-Server Network Architecture (1)



Main Features

- Only rendered images sent back
- Data transfer minimization
- Security assurance → SSH tunnel

HELYX Client-Server Network Architecture (2)

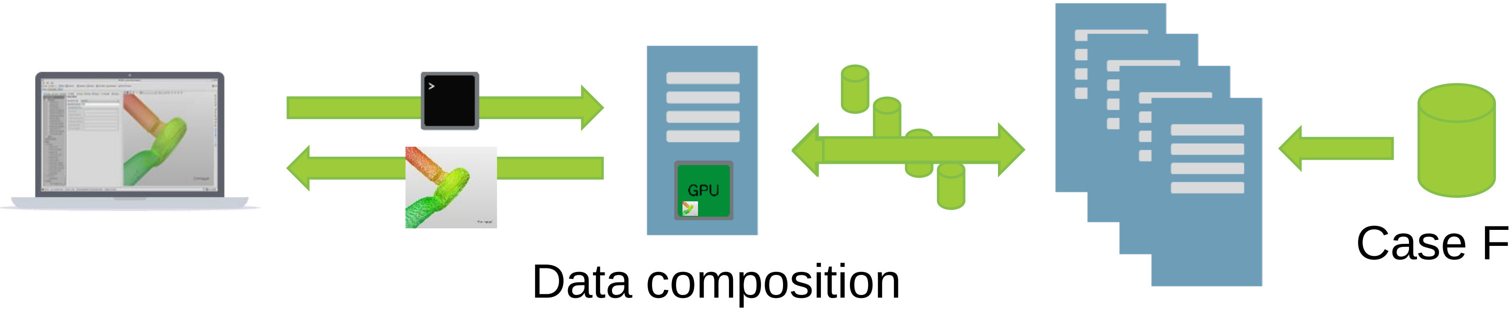


Local Machine

Remote Machine

Application Scenarios

- **GPU Rendering**

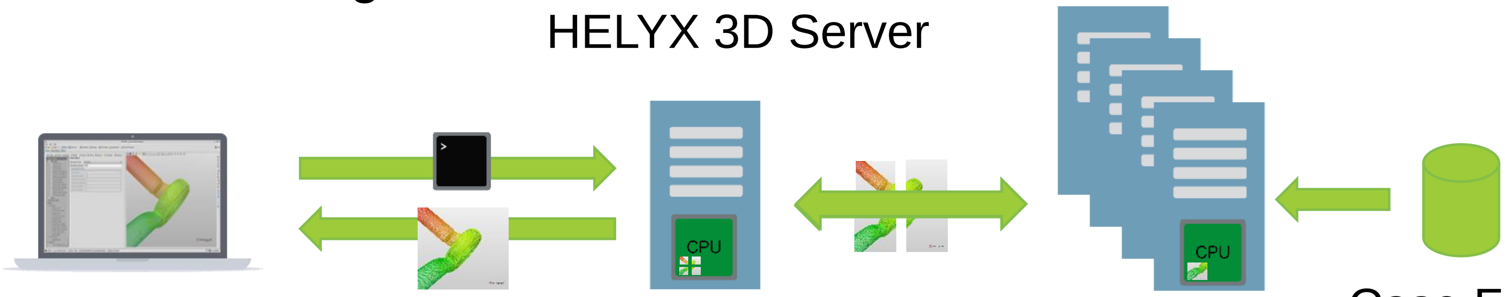


HELYX 3D Server

Data composition

Case Folder

- **Software Rendering**

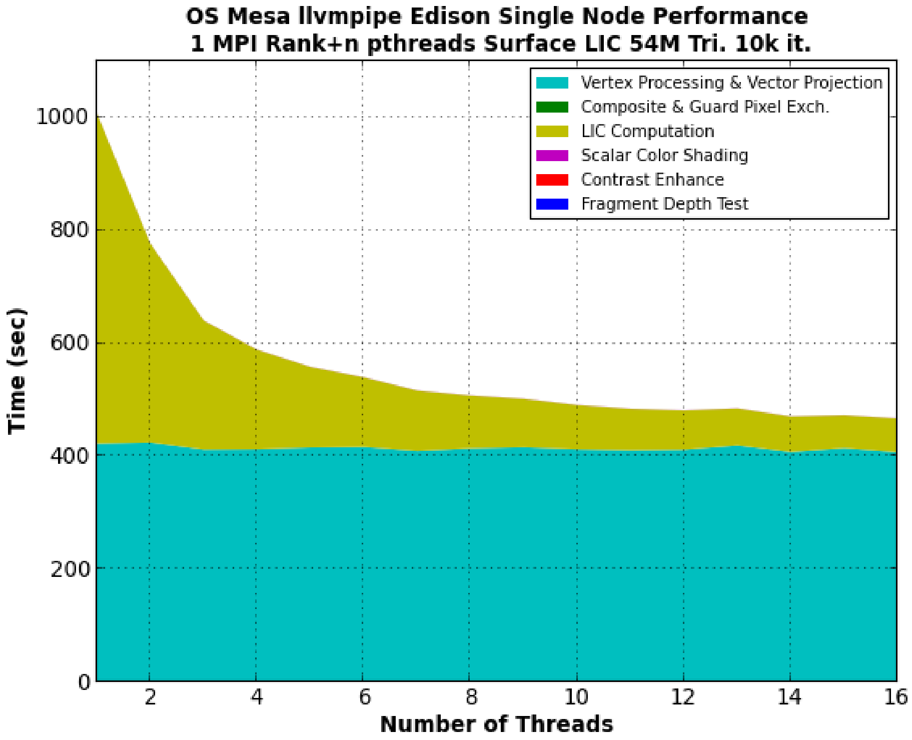


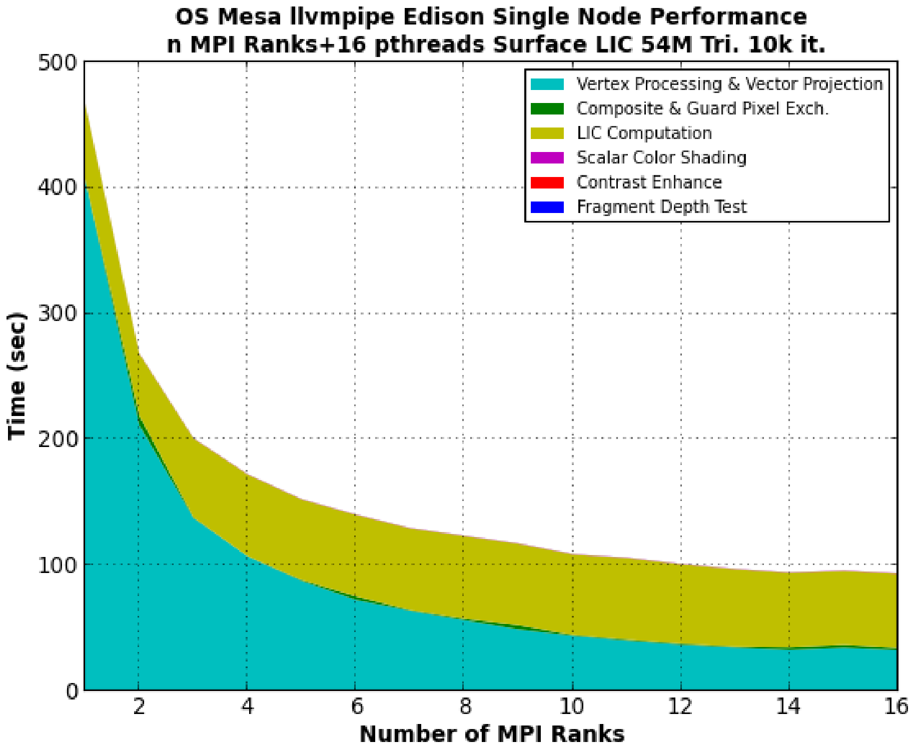
HELYX 3D Server

LLVM-PIPE

Case Folder

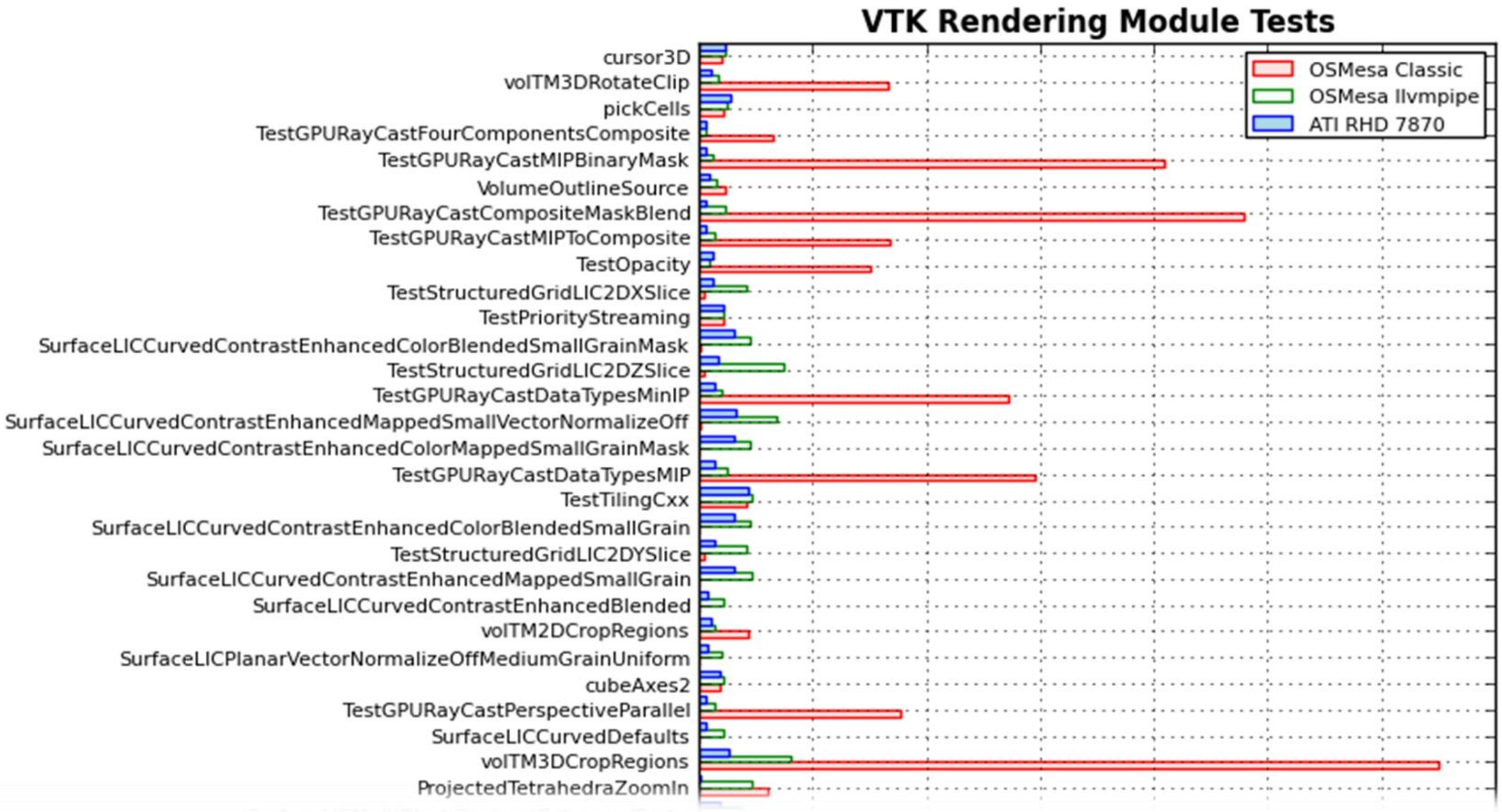
LLVM-Pipe Algorithm Performance (1)





Ref: http://www.paraview.org/Wiki/ParaView/ParaView_And_Mesa_3D

LLVM-Pipe Algorithm Performance (2)



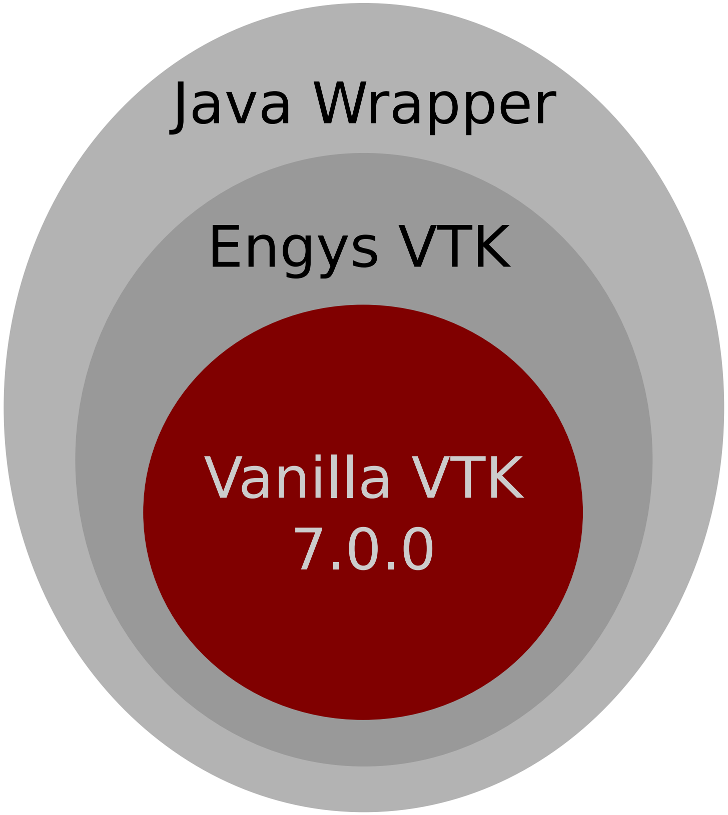
Ref: http://www.paraview.org/Wiki/ParaView/ParaView_And_Mesa_3D

VTK 7.0.0

- New OpenGL 2 backend (+ 6M GPU primitives)
- Java wrapper support
- Rendering ~350 times faster than v6.x.x
- MPI support
- Off-screen rendering through OSMesa
- Composite rendering

VTK 7.0.0 – ENGYS Edition

- High complexity structures at C++ side modified by ENGYS
- Java side: high-level objects only
- Enhanced efficiency and performance



Java Wrapper

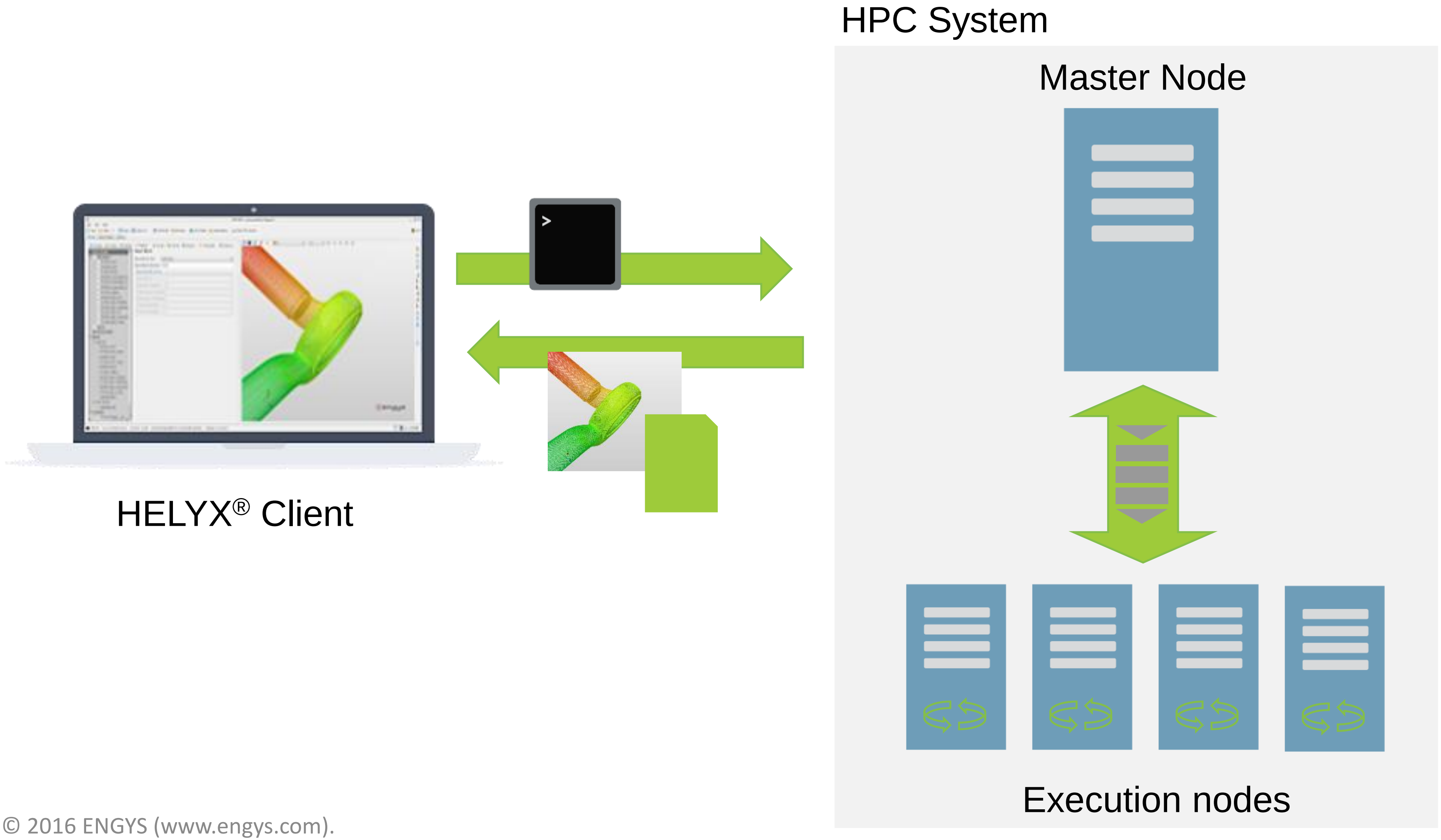
Engys VTK

Vanilla VTK 7.0.0

HELYX® HPC Usage (1)

- Remote execution (via SSH)
- Case data located at server side only
- Lightweight client application
- Computational complexity at server side
- Headless (no GPU) cluster support
- Queue system support (PBS, SGE, etc.)

HELYX® HPC Usage (2)



HPC System

Master Node

Execution nodes

HELYX® Client

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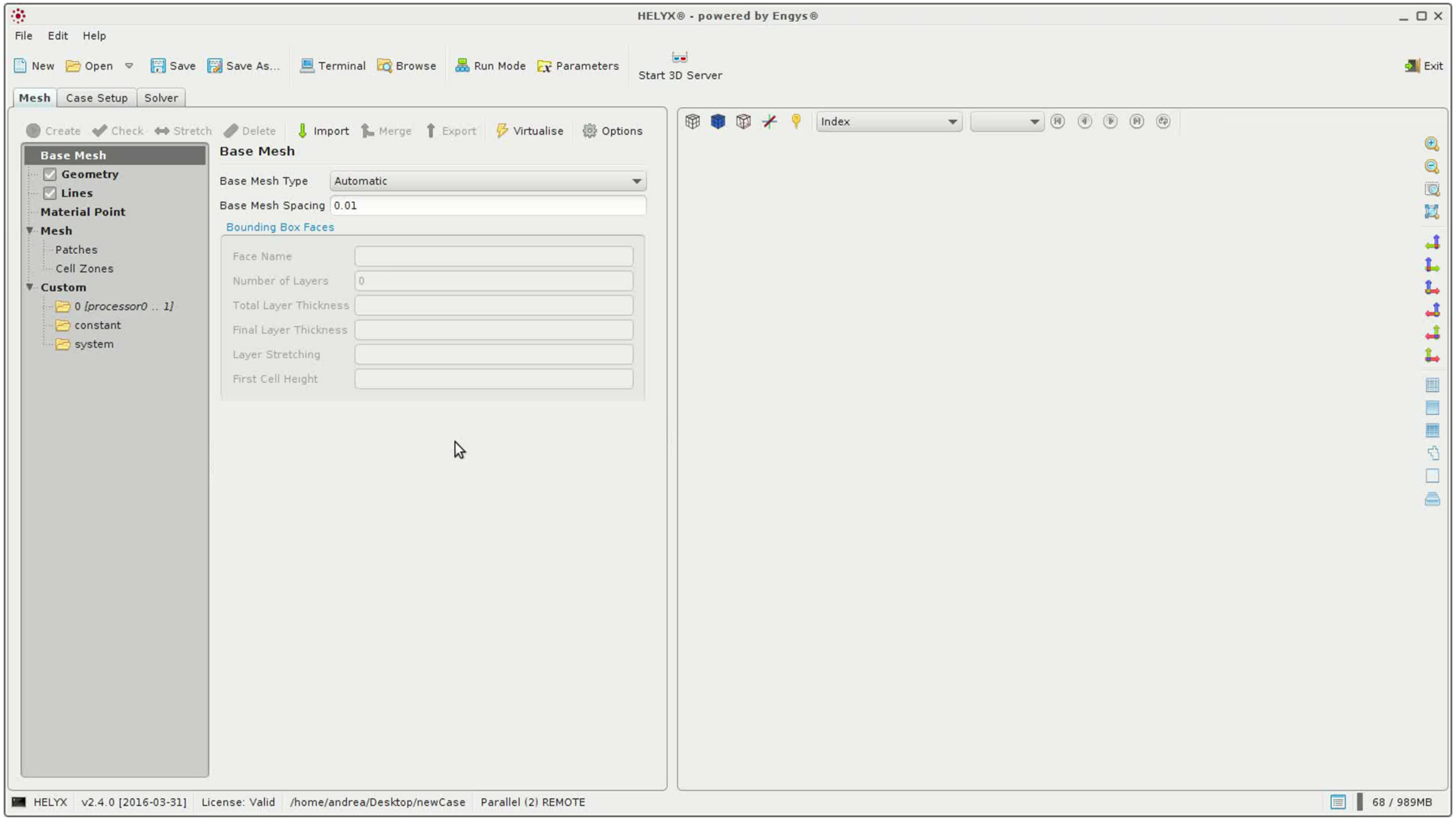
DEMO: HELYX® Usage



HELYX® - powered by Engys®

Base Mesh

Base Mesh Type: Automatic

Base Mesh Spacing: 0.01

Bounding Box Faces

Face Name:

Number of Layers: 0

Total Layer Thickness:

Final Layer Thickness:

Layer Stretching:

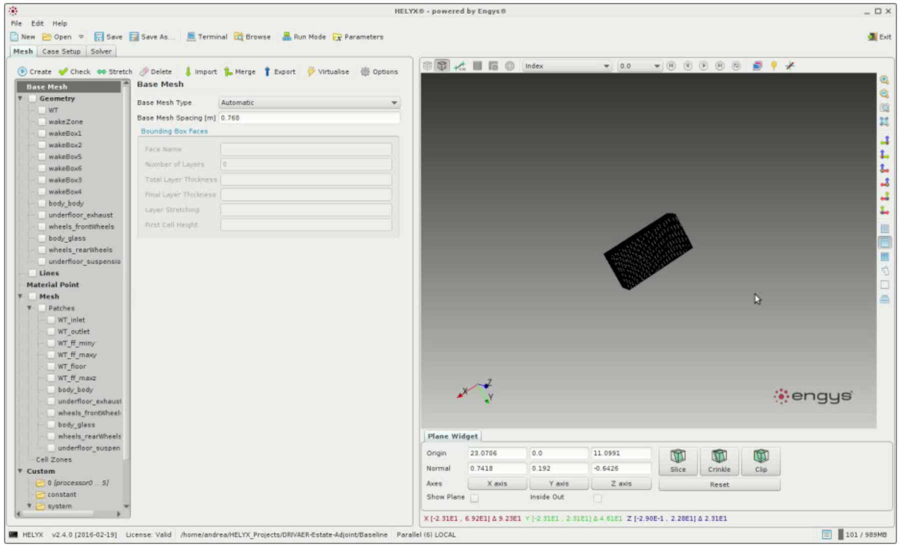
First Cell Height:

- Base Mesh
  - ☑ Geometry
  - ☑ Lines
- Material Point
- Mesh
  - Patches
  - Cell Zones
- Custom
  - 0 [processor0 .. 1]
  - constant
  - system

HELYX | v2.4.0 [2016-03-31] | License: Valid | /home/andrea/Desktop/newCase | Parallel (2) REMOTE | 68 / 989MB

DEMO: New Rendering Engine

VTK 6.1 Rendering Engine



Base Mesh

Base Mesh Type: Automatic

Base Mesh Spacing [m]: 0.768

Bounding Box Faces

Face Name:

Number of Layers: 0

Total Layer Thickness:

Final Layer Thickness:

Layer Stretching:

First Cell Height:

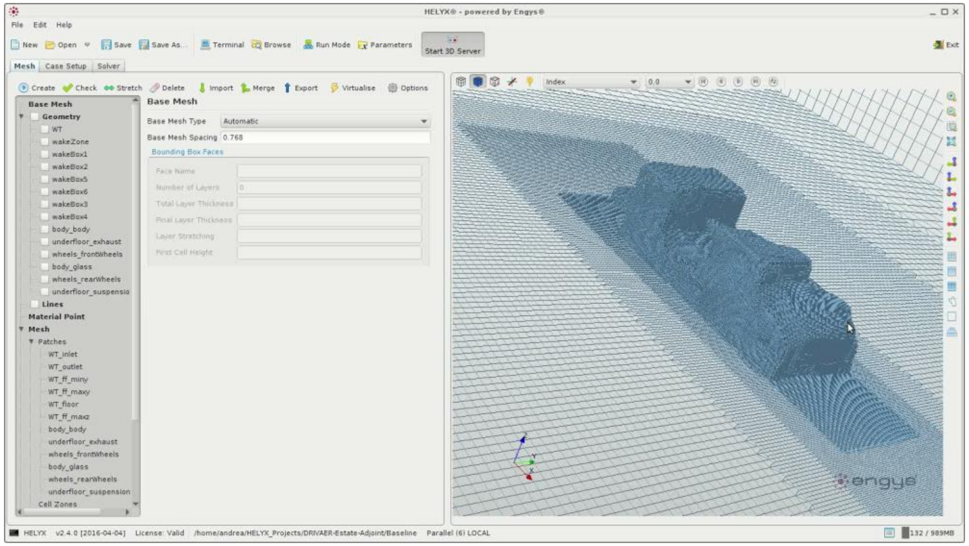
Origin	23.0706	0.0	11.0991
Normal	0.7418	0.192	-0.6426
Axes	X axis	Y axis	Z axis

Show Plane ☐ Inside Out ☐

X [-2.31E1 , 6.92E1] Δ 9.23E1 Y [-2.31E1 , 2.31E1] Δ 4.61E1 Z [-2.90E-1 , 2.28E1] Δ 2.31E1

HELYX v2.4.0 [2016-02-19] License: Valid /home/andrea/HELYX_Projects/DRIVAER-Estate-Adjoint/Baseline Parallel (6) LOCAL 101 / 989MB

VTK 7.0.0 Rendering Engine



Base Mesh

Base Mesh Type: Automatic

Base Mesh Spacing: 0.768

Bounding Box Faces

Face Name:

Number of Layers: 0

Total Layer Thickness:

Final Layer Thickness:

Layer Stretching:

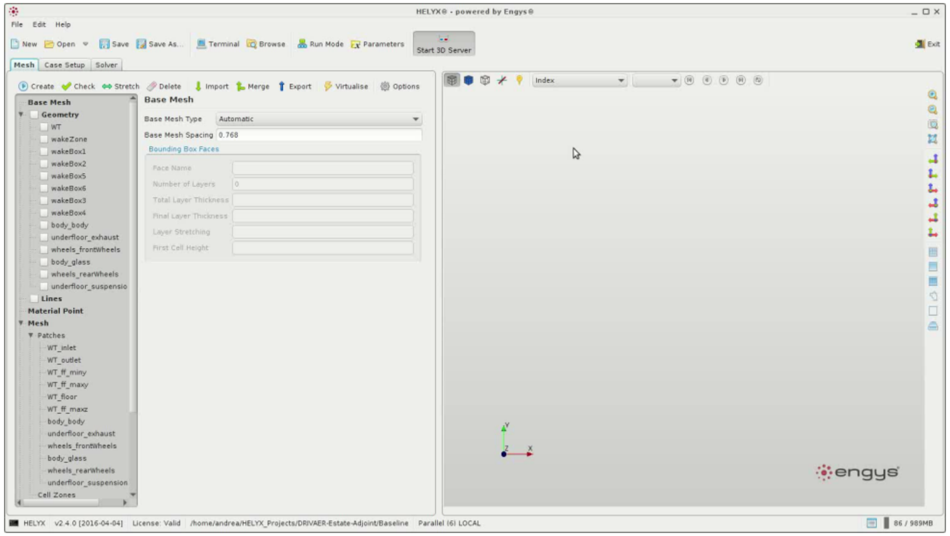
First Cell Height:

HELYX v2.4.0 [2016-04-04] License: Valid /home/andrea/HELYX_Projects/DRIVAER-Estate-Adjoint/Baseline Parallel (6) LOCAL 132 / 989MB

Mesh size: 58.260.284 cells

DEMO: Serial vs Parallel Reader

Serial Reader



Base Mesh

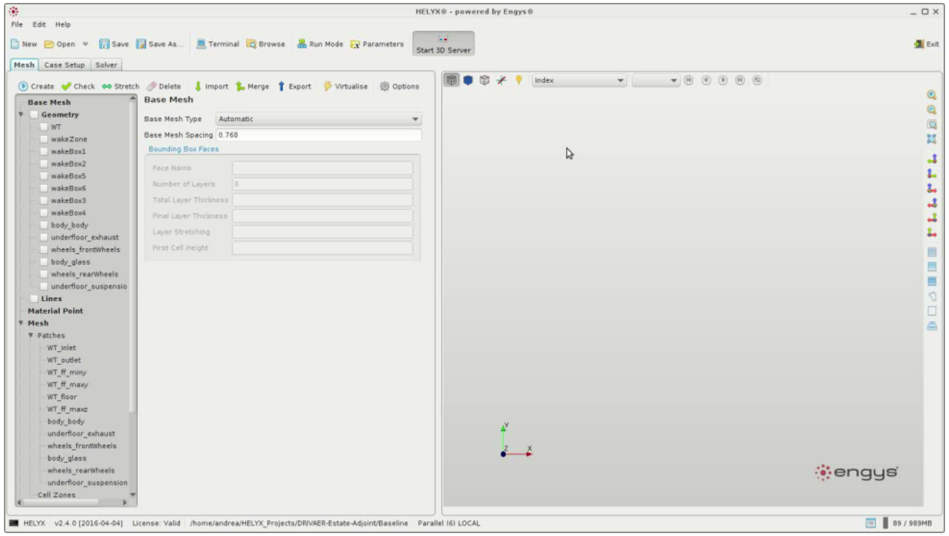
Base Mesh Type: Automatic
Base Mesh Spacing: 0.768

Bounding Box Faces

Face Name:
Number of Layers: 0
Total Layer Thickness:
Final Layer Thickness:
Layer Stretching:
First Cell Height:

HELYX v2.4.0 [2016-04-04] License: Valid /home/andrea/HELYX_Projects/DRIVAER-Estate-Adjoint/Baseline Parallel (6) LOCAL 86 / 989MB

Parallel Reader (Rank 6)



Base Mesh

Base Mesh Type: Automatic
Base Mesh Spacing: 0.768

Bounding Box Faces

Face Name:
Number of Layers: 0
Total Layer Thickness:
Final Layer Thickness:
Layer Stretching:
First Cell Height:

HELYX v2.4.0 [2016-04-04] License: Valid /home/andrea/HELYX_Projects/DRIVAER-Estate-Adjoint/Baseline Parallel (6) LOCAL 89 / 989MB

	Serial	Parallel
# of Processes	1	6
Mesh Size	3.881.803	3.881.803
Scenario	GPU Rendering	GPU Rendering
Time [ms] *	124.296	26.936

(*) Inclusive of both reading and rendering time

~4,50 times faster

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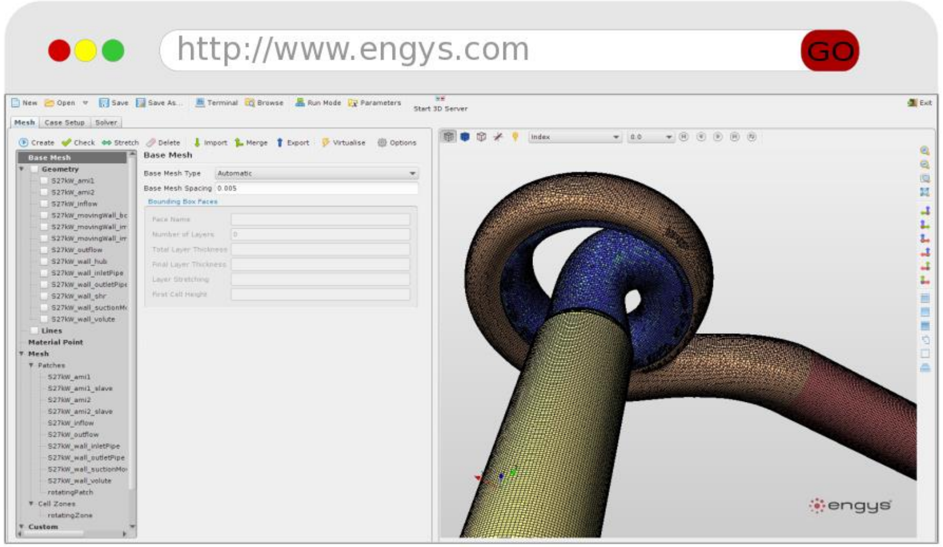
Future Developments

- HELYX®-Server as Web Service
  - Browser access
  - Mobile Client



Base Mesh

Base Mesh Type: Automatic

Base Mesh Spacing: 0.005

Bounding Box Faces

Face Name:

Number of Layers: 0

Total Layer Thickness:

Final Layer Thickness:

Layer Stretching:

First Cell Height:

References

- *OpenGL - The Industry's Foundation for High Performance Graphics*, https://www.opengl.org, 2016
- E. Miretsky, *Software based GPU framework*, Ph.D. dissertation, 2013.
- D. DeMarle, B. Boeckel, and C. Atkins.,*VTK 7.0.0.* https://blog.kitware.com/vtk-7-0-0/, 2016
- Kitware, *Vtk/api changes 6.3.0 to 7.0.0.*, 2016.
- T. Richardson and K. R. Wood, *The rfb protocol*, *ORL, Cambridge, January*, 1998.
- http://www.paraview.org, 2016

Thank You!

Questions?