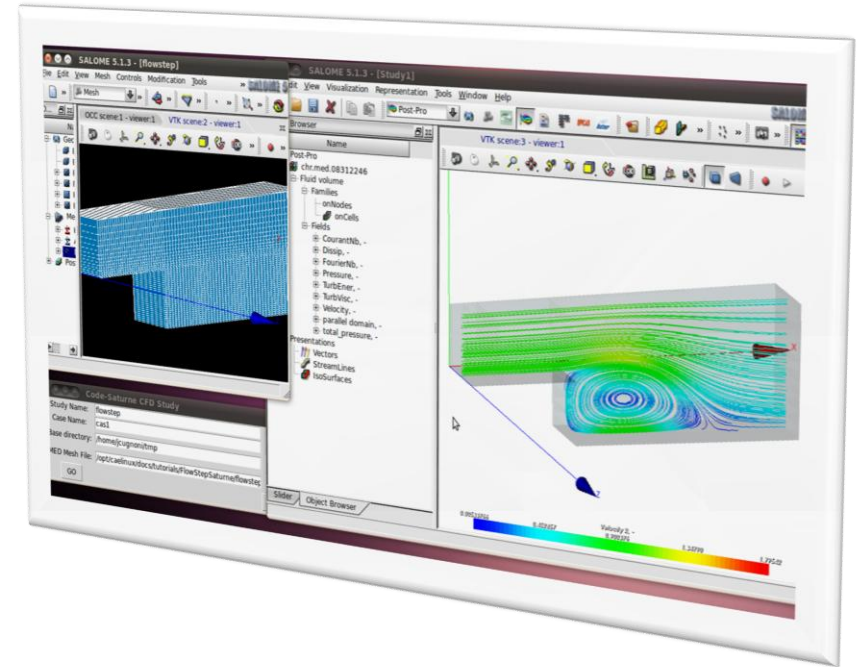
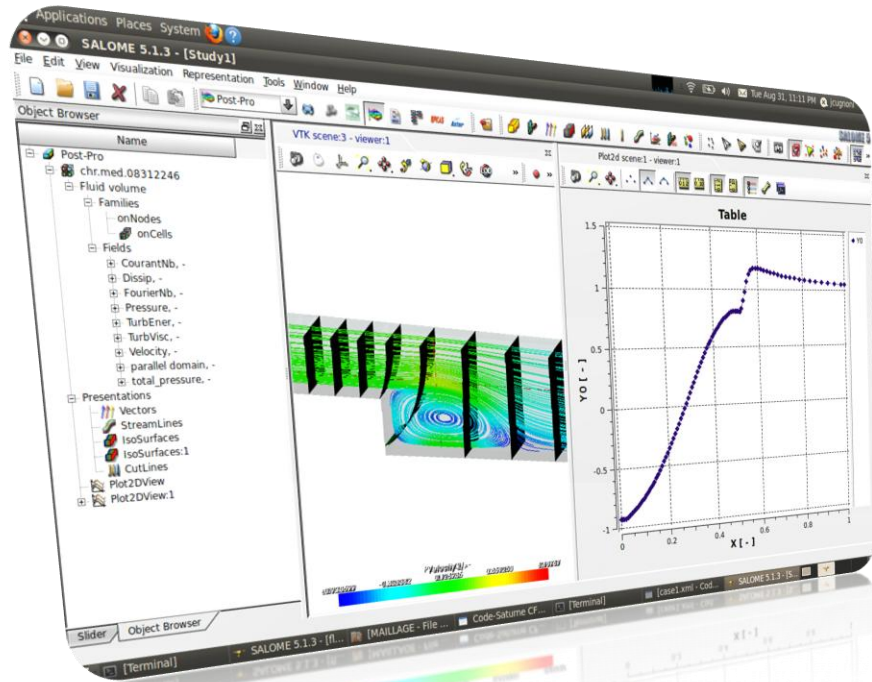


# CAELinux : an open source engineering platform



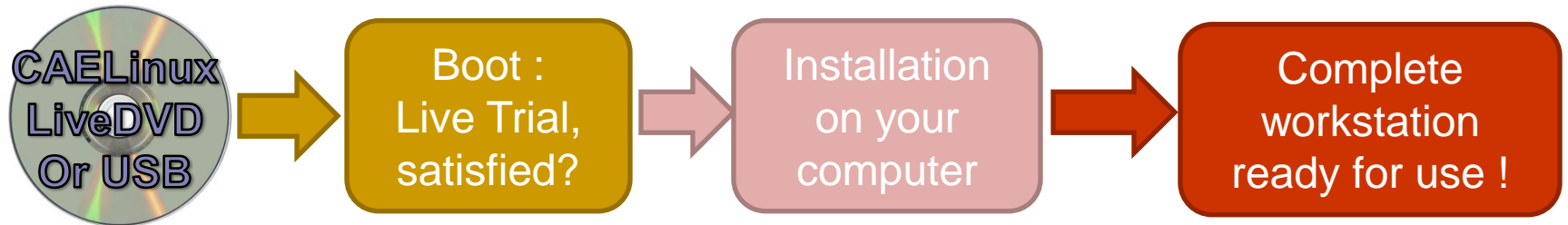
Joël Cugnoni, [www.caelinux.com](http://www.caelinux.com)

# What is CAELinux ? A CAE workstation on a disk

## o CAELinux in brief

- CAELinux is a « Live » Linux distribution pre-packaged with the main open source Computer Aided Engineering software available today.
- CAELinux is free and open source, for all usage, even commercial (\*)
- It is based on Ubuntu LTS (12.04 64bit for CAELinux 2013)
- It covers all phases of product development: from mathematics, CAD, stress / thermal / fluid analysis, electronics to CAM and 3D printing

## o How to use CAELinux:



Or



CAELinux virtual Machine installation in OSX, Windows or other Linux

Running a server in Amazon EC2 cloud computing (on demand, charge per hour)

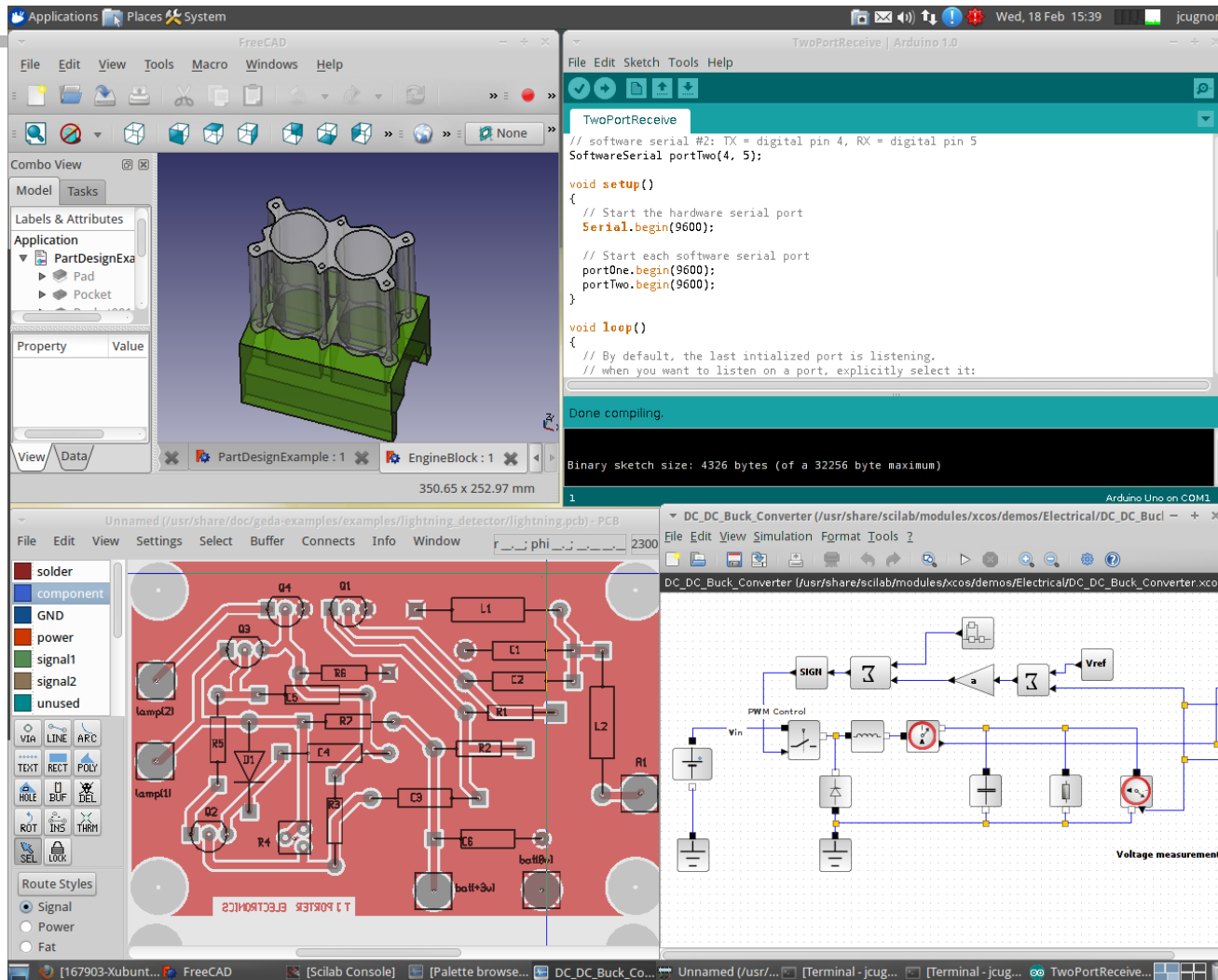


# CAELinux: History and present

## o Past and present:

- CAELinux started in 2005 as a personal project for my own use
- Motivation was to promote the use of scientific open source software in engineering by avoiding the complexities of code compilation and configuration. And also, I wanted to have a reference installation of Code-Aster and Salome that I could install for my own use.
- Until now, 11 versions have been released in ~9 years. One release per year (except 2014).
- Today, the latest version, CAELinux 2013, has reached 63'000 downloads in 1 year on sourceforge.net.
- CAELinux is used for teaching in universities, in SME's for analysis and by many occasional users, hobbyists, hackers and Linux enthusiasts.
- The main distribution is still developed by myself on my free time which explains the slow updates.
- A community has formed around CAELinux with many contributors participating in the documentation, tutorials and support on forums and wiki

# What can you do with it?



CAD/electronics and system simulation: FreeCAD, gEda, Arduino, Scilab/Xcos

# What can you do with it?

The screenshot displays a Linux desktop environment with several windows open. The main window is QtOctave [Empty], which shows a 3D surface plot of a function. The plot is titled "Figure 1" and shows a colorful surface with a peak in the center. The axes are labeled with values from -10 to 10. The Octave Terminal window shows the following code:

```
>>> tx = ty = linspace (-8, 8, 41)';  
>>> [xx, yy] = meshgrid (tx, ty);  
>>> r = sqrt (xx .^ 2 + yy .^ 2) + eps;  
>>> tz = sin (r) ./ r;  
>>> mesh (tx, ty, tz);
```

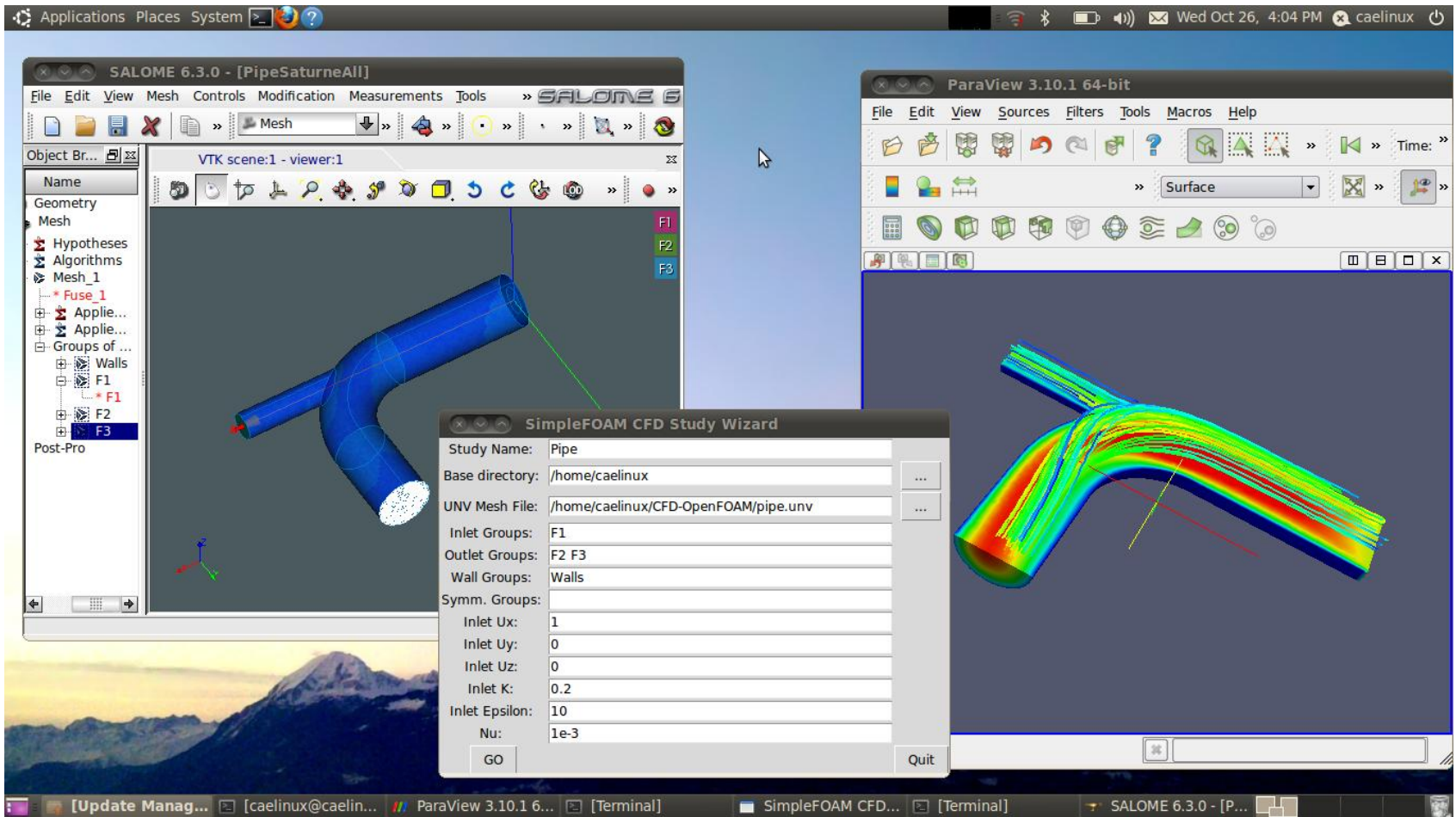
The wxMaxima 0.8.4 [unsaved\*] window shows the following code:

```
(%i5) integrate(1/(sqrt(x)+1),x);  
(%o5) 2*(sqrt(x)+1)-2*log(sqrt(x)+1)  
(%i8) plot2d(%o5,[x,0,1]);
```

The Gnuplot (window id : 0) window shows a 2D plot of the function  $2*(\sqrt{x}+1)-2*\log(\sqrt{x}+1)$  versus  $x$ . The plot is a straight line with a positive slope, ranging from  $x=0$  to  $x=1$ . The y-axis ranges from 2 to 2.7. The plot is titled "Gnuplot (window id : 0)" and shows the command `plot2d(%o5,[x,0,1])`.

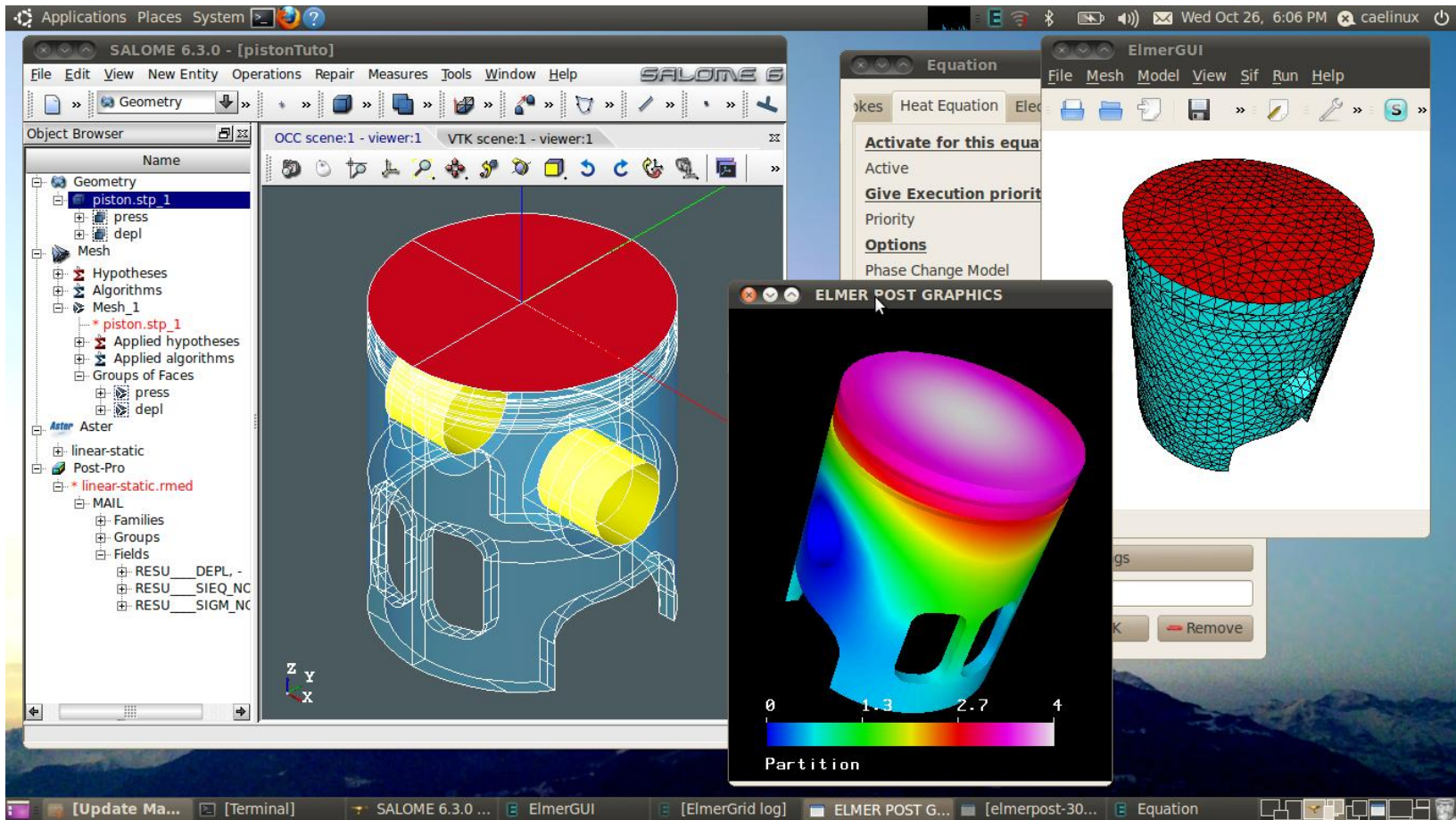
Mathematical modeling and programming: Octave, Maxima, R, Python/Scipy

# What can you do with it?



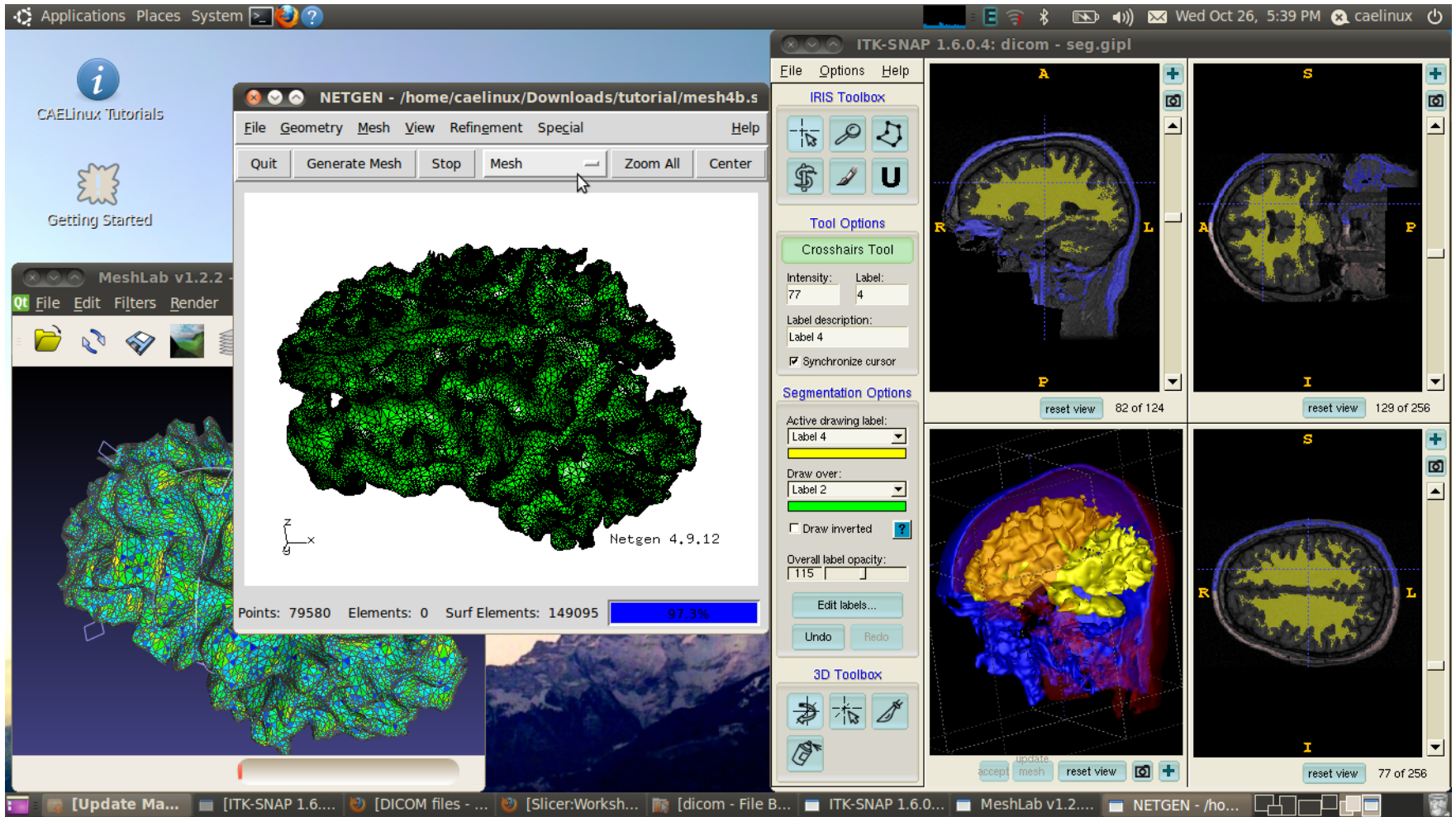
CFD: Salome / OpenFOAM or Code-Saturne

# What can you do with it?



Thermo mechanics: Salome / Elmer or Code-Aster or Calculix

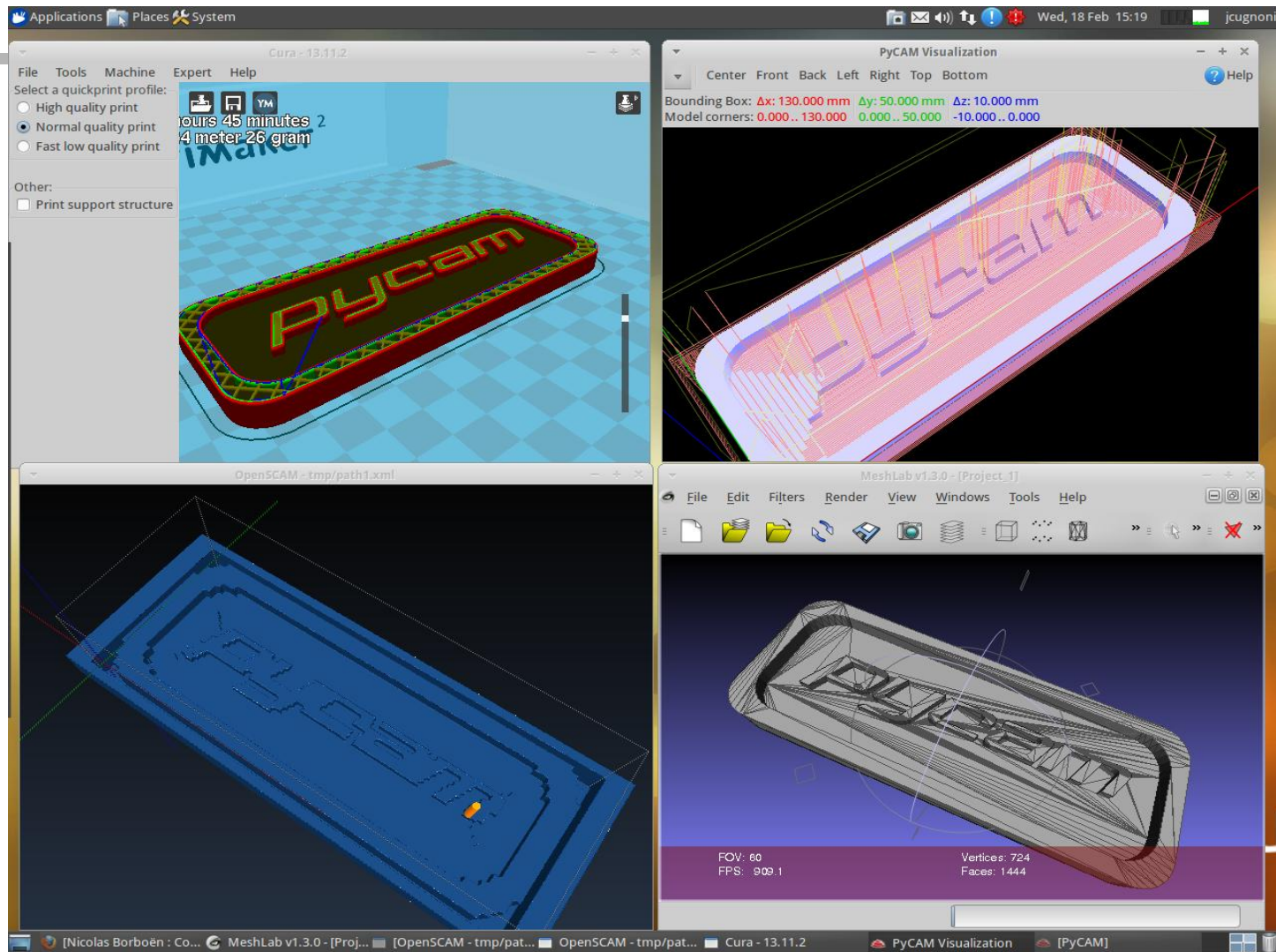
# What can you do with it?



Biomedical image analysis and modeling: ITKSnap / VoxelMesher/ Calculix



# What can you do with it?



CAM, milling simulation, 3D printing: Pycam, PCB2Gcode, OpenSCAM, Cura

# What is in CAELinux ?

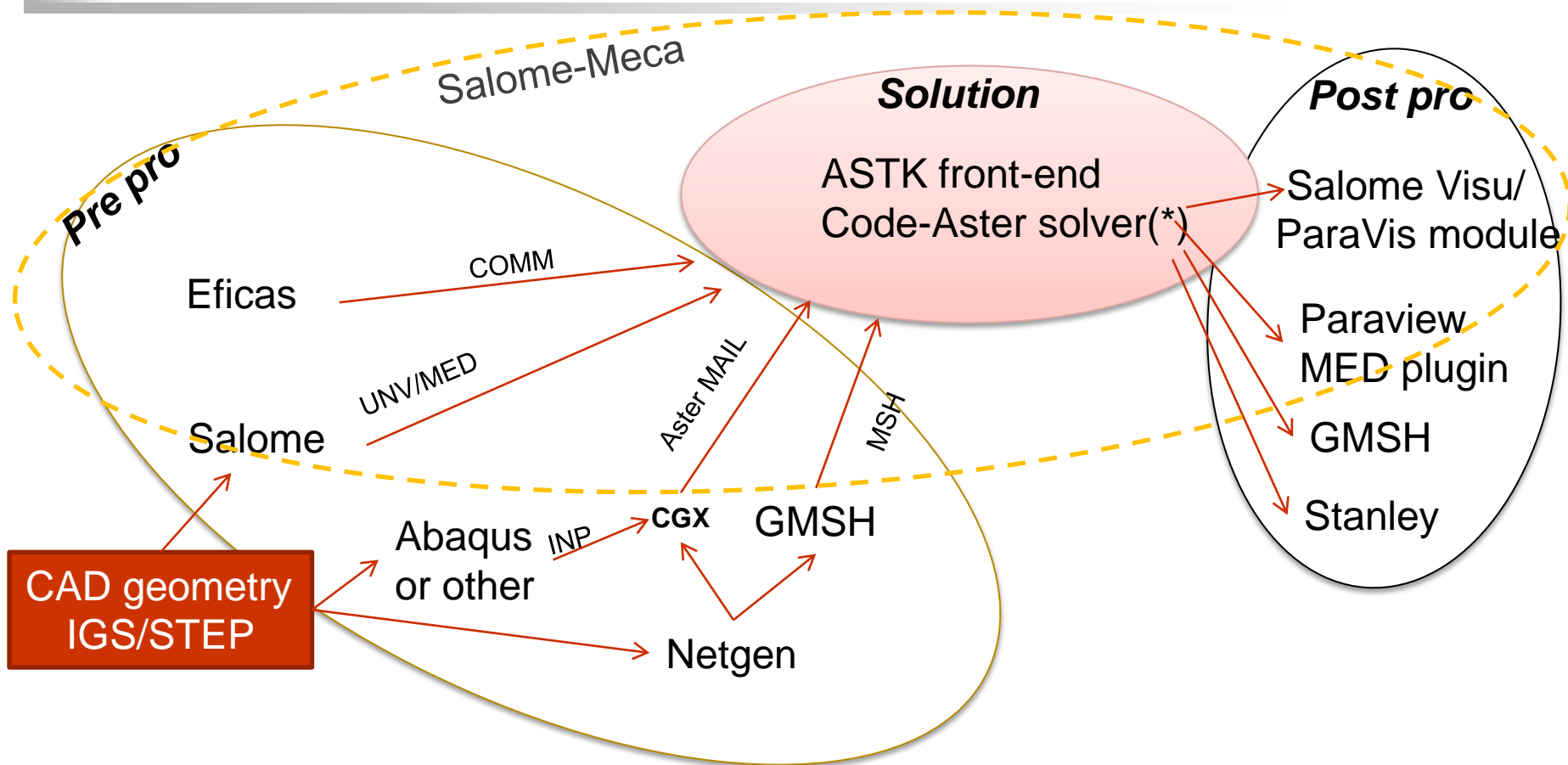
## CAE analysis process

- Design, Meshing , Pre-pro
  - FreeCAD
  - Salome
  - GMSH
  - Netgen
  - HelyxOS
  - EnGrid
  - Discretizer
  - ElmerGUI
  - CGX
  - ...

- Solvers:
  - Code-Aster (FE)
  - Code-Saturne (CFD)
  - Syrthes (FE, thermo)
  - OpenFOAM (FV, CFD/multiphysics)
  - Elmer (FE / Multiphysics)
  - Impact (FE)
  - Gerris (FV, CFD)
  - MBDyn (Multibody)
  - ...

- Visu, post-pro
  - Salome
  - GMSH
  - Paraview
- Math / plotting
  - Octave
  - Scilab
  - Maxima
  - R
  - Scipy
  - Gnuplot
  - ...

# Code-Aster Workflow in CAELinux



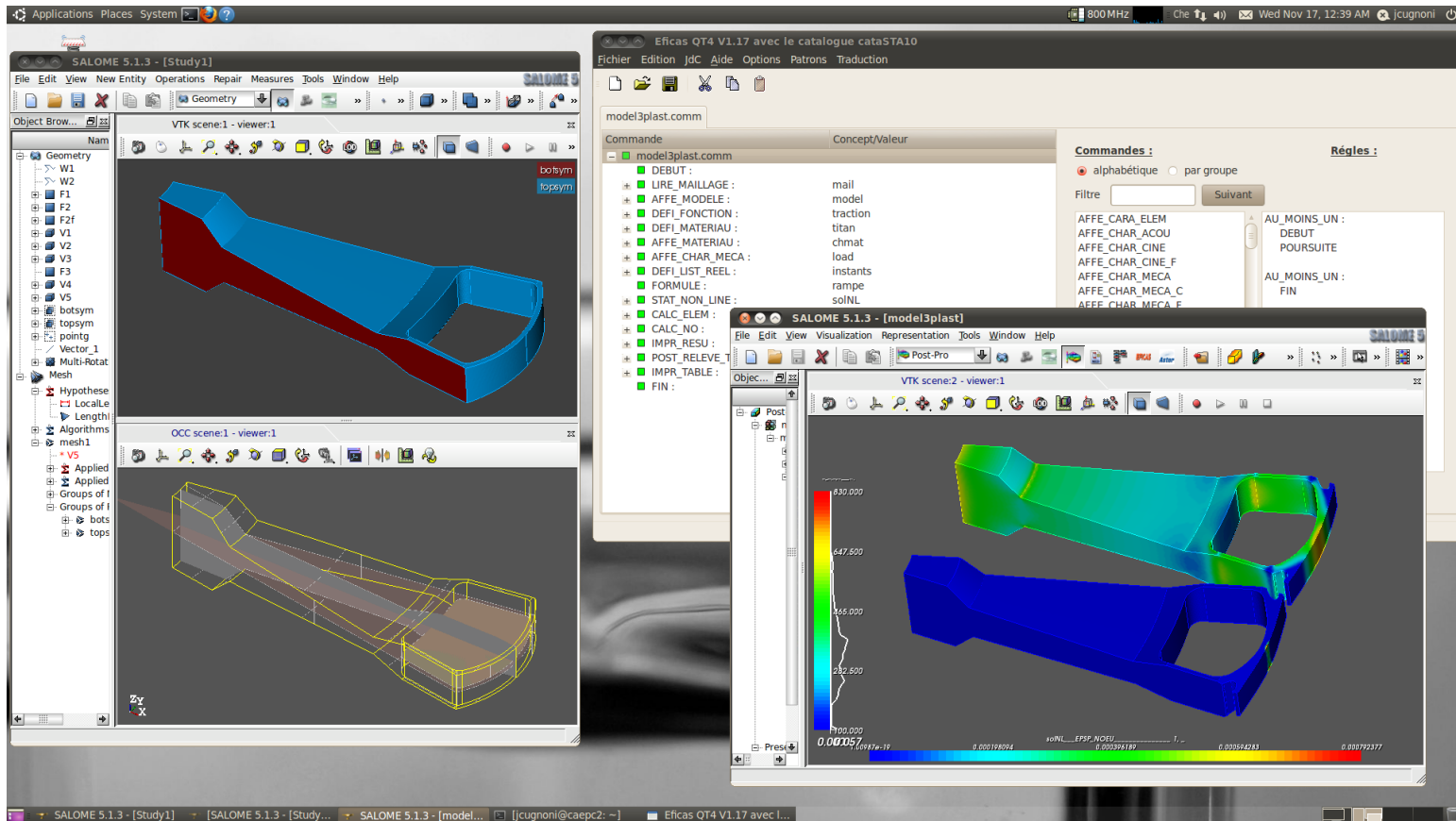
- Two versions of Code-Aster are available in CAELinux:
  - STA and NEW from Salome-Meca with OpenMP parallelism (MULT\_FRONT solver)
  - Custom NEW MPI version with PETSC & MUMPS parallel solvers in /opt/aster

# CAELinux / Aster documentation: how to get started

- Getting started:
  - CAELinux Wiki (<http://www.caelinux.org>): many valuable tutorials, some interactive, some on PDF, different level of complexity. Many user contribution in “Contrib” section!
  - Code-Aster.org: free & high quality Training material (<http://www.code-aster.org/V2/spip.php?article282> )
  - Salome-Platform.org: Salome tutorials for all levels (<http://salome-platform.org/user-section/salome-tutorials> )
- Documentation on Code-Aster.org :
  - Start with U2 methodological documents, very valuable guidelines & tips
  - Identify the main commands to use and read the U4 docs
  - In case you need it, read the corresponding Reference doc to understand the theory behind
  - Find an validation test (V doc) or search (grep?) in “Aptest” folder for a COMM file that is close to what you need, try to replicate it and check.

# Salome / Code-Aster: examples

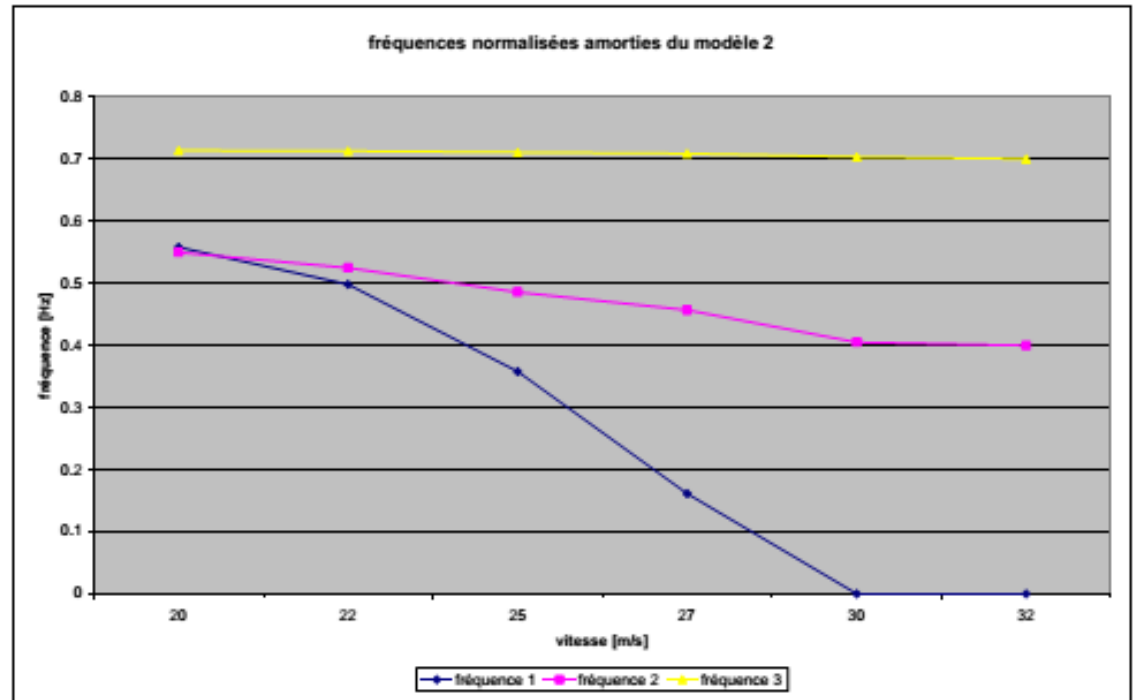
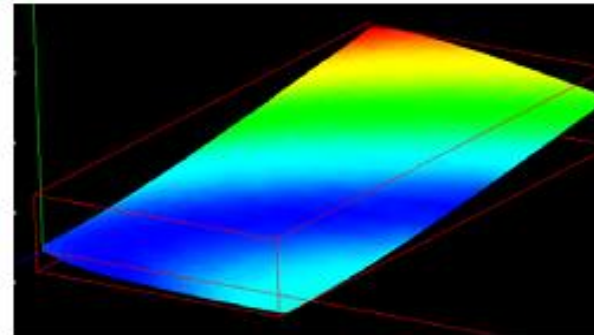
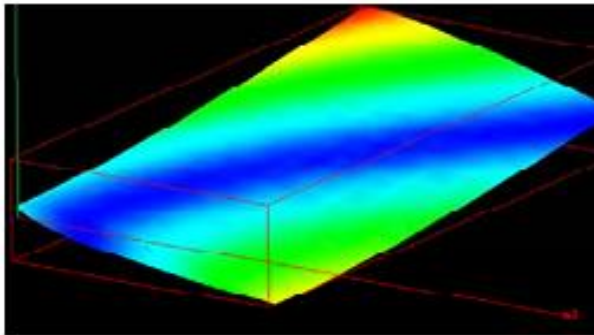
**Optimization:** Salome + Python + Scipy => Parametric FEA => Code-Aster solver



Flexibility of the platform: Python used for external optimization loop (Scipy), in Salome for parametric CAD/FE mesh & within Aster solver for custom post-pro

# Fluid-structure interactions

## Added mass, wet eigen frequencies and divergence of an hydrofoil

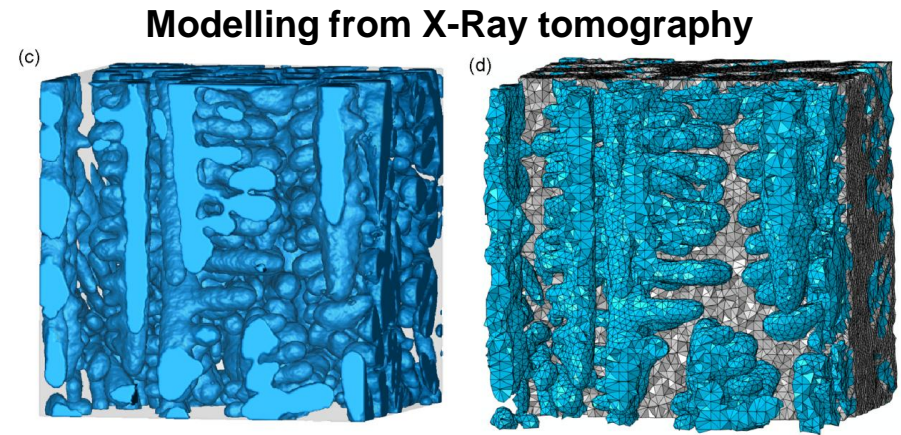
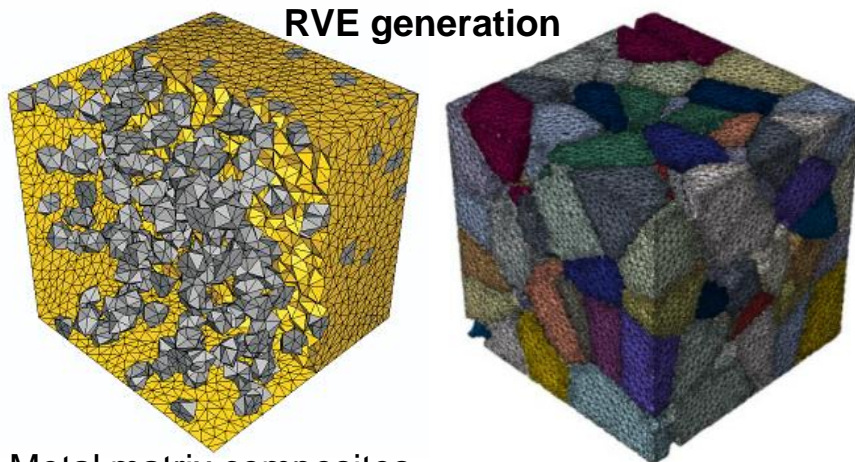


**Advantage:** unique possibilities of Code-Aster to compute added mass, stiffness and damping from a potential theory.

**Issue:** hard to validate because of lack of experimental data...

# Future work & needs (Research at EPFL)

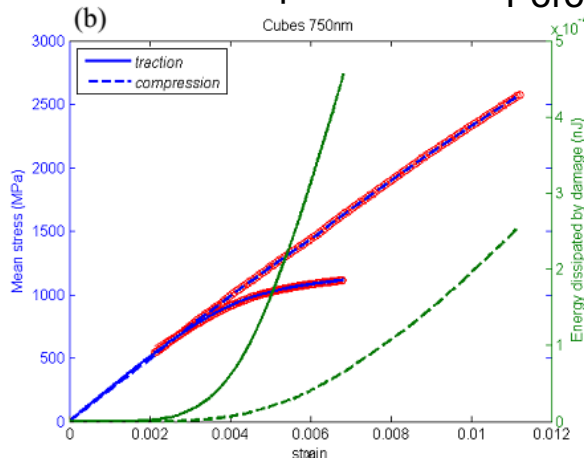
- o Migrate homogenization methods developed at LMAF to Code-Aster



Metal matrix composites

Porous ceramics

Alloys ( here SnAgCu solder)



## Opportunity:

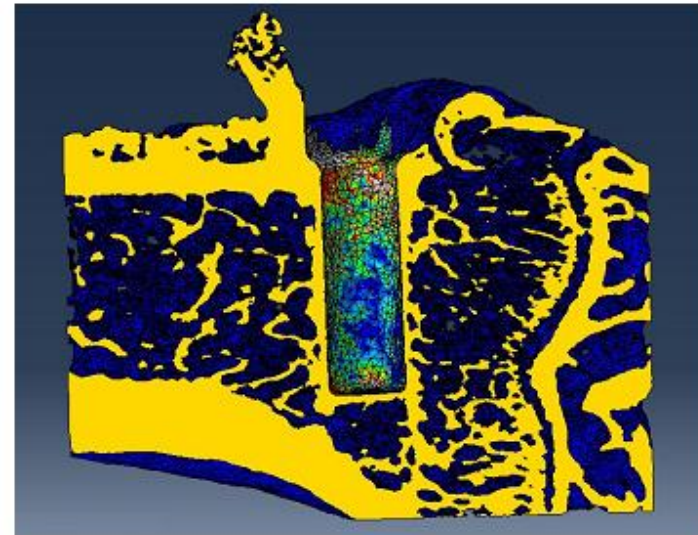
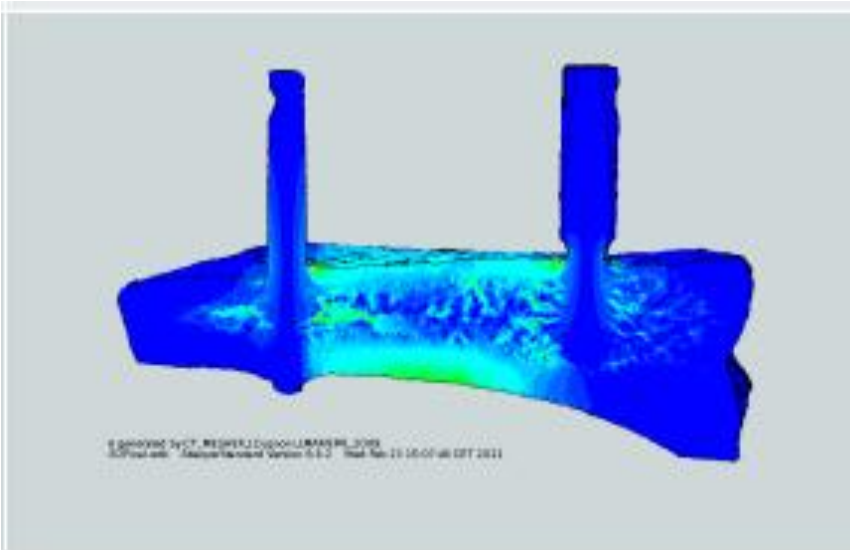
develop an open source homogenization platform (equivalent to Digimat)

## Need:

- high performance parallel processing in non-linear problems & robust solvers, maybe dynamic (explicit)
- cohesive contact models (not elements)

## Future work & needs (Research at EPFL)

- Migrate LMAF's bone modeling tools (VoxelMesher) to Code-Aster



### **Opportunity:**

develop an open source platform for biomedical engineering

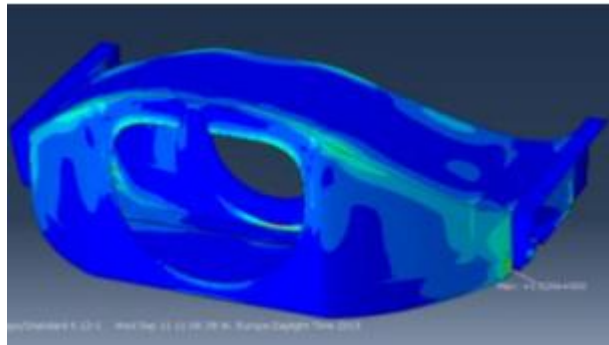
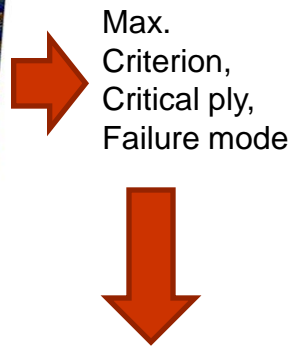
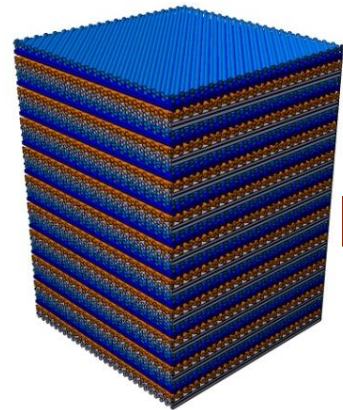
### **Need:**

-time to write a mesh writer to Aster (MAIL format) & implement element-wise elastic properties in a COMM file using an external file as input

-cohesive contact models for interface modeling, Drucker-Prager plasticity with damage and efficient parallel solvers (>3MDof)



# Future work & needs (Research at EPFL)



Max envelop of layerwise criteria

- Further development of Composite modeling tools:
  - Regression, resorption of features in this field recently
  - Improved & simplified inputs for multilayer shells (one MACRO?)
  - Improved performance & simplicity for multilayer shell post-processing and composite failure criteria : implementation of Hashin/Puck, Tsai-Hill, Tsai-Wu, LARC, Hoffman failure criteria
  - Faster post-processing (not layer by layer): computation of envelope of maximum inverse safety factor and critical ply number and failure type through all layers => one field with all relevant results
  - Further development of mixed mode cohesive models for delamination simulation

# Code-Aster and CAELinux: experience

- What works well:
  - Versatility and flexibility of Code-Aster / Salome / GMSH environment is great
  - Many complex simulations are possible, many tuning options
  - Very open to code coupling and file transfers, integration with external tools and custom developments in Python or Fortran
  - Requires a trained user which knows what is behind (this is a + in the end)
  - Diffusion of Aster through Salome-Meca is great
  - Frequent updates of Code-Aster, valuable forum and feedback from Devs
  - Aster is at the fore front of research in some domains but remains a generalist FEA solver with excellent multiphysics capabilities
  - Many improvement in parallel solution performance recently, becomes also more robust with contacts
  
  - For CAELinux: it has found a great audience, is used worldwide!

# Code-Aster and CAELinux: experience

- What could be improved:
  - English doc is hard to read... start an open human « translation project »?
  - More methodological docs & intermediate level tutorials to ease learning
  - Salome Wizards could be expanded to help the transition between beginner and expert levels
  - Small community, needs more interactions to keep it alive
  - Default settings in non-linear solution and automatic time stepping could be improved for better performance. Trying to replicate (and set as default) Abaqus time stepping / convergence analysis would be highly beneficial.
  - Display performance issues in Salome Mesh & Visu but improved recently
  - Some inconsistencies in post-processing, issues with Von Mises in tetrahedra, slow post-processing (CALC\_CHAMP) compared to solver...
  - Deploying Linux in companies remains an issue, even with Virtual Machines
  - More synergies between actors should be found to mutualize development / training and support
  - For CAELinux: should migrate to an open development model

# CAELinux: Development and future

## o Development process:

- CAELinux uses Ubuntu LTS 64 bit as a base and Remastersys to build the final ISO image of the distribution
- Use as much as possible existing Debian/Ubuntu packages, but some are outdated or lacking features like parallel solvers.
- Build « hand made » packages for key CAE software such as Code-Aster, Code-Saturne, Elmer to use recent versions and enable parallel MPI solvers and optimized math libraries
- Building a reference image with all chosen packages and final customization (desktop layout, shortcuts, docs & tutorials) using Remastersys.

## o Future

- Development of each package and production / testing of the final distribution is still mostly manual and iterative but ensures good stability.
- Moving to collaborative development is a goal but transition is difficult
- a new release is planned for Q4 2015 based on Ubuntu 14.04.

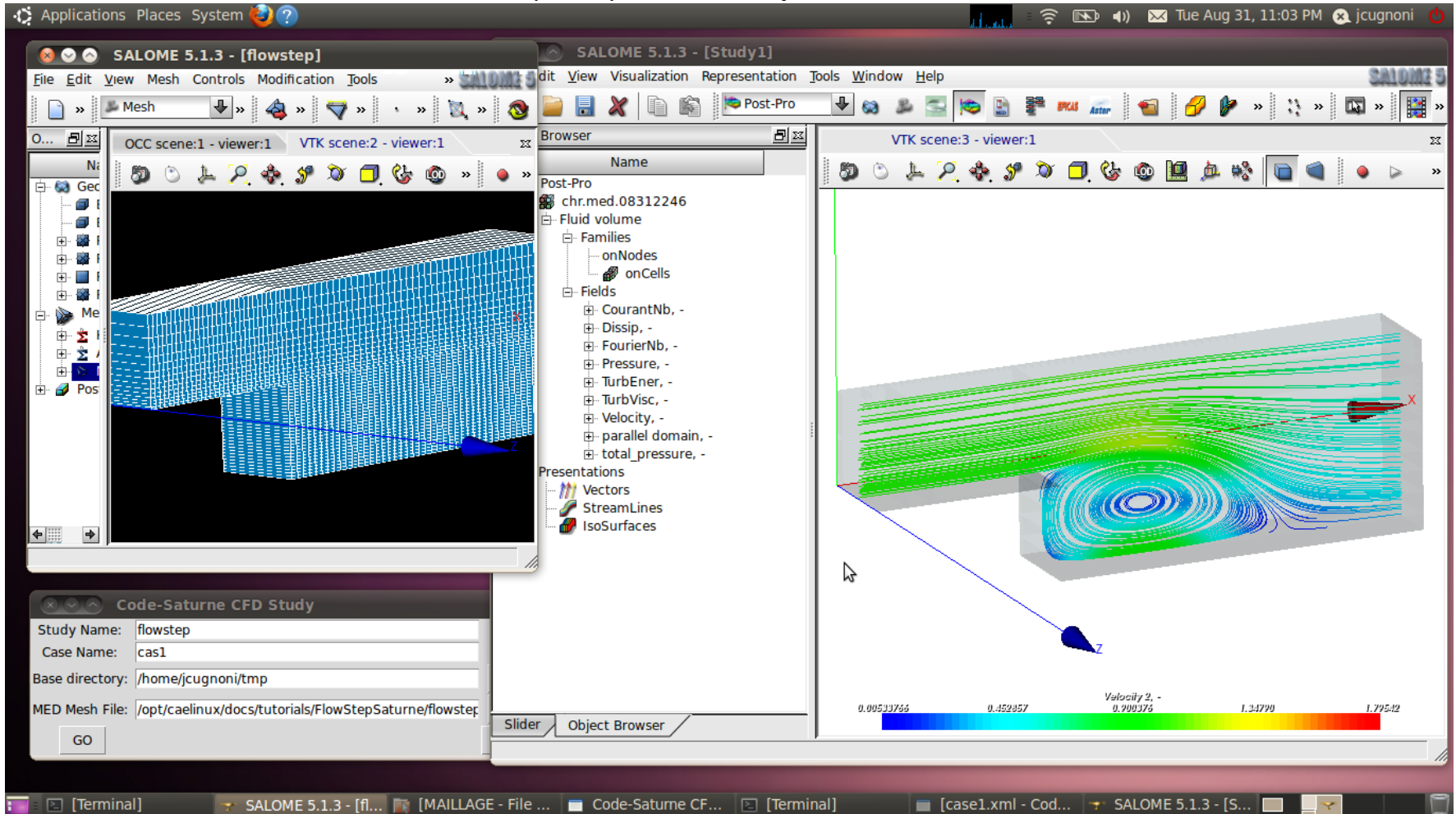


**Merci de votre attention !**

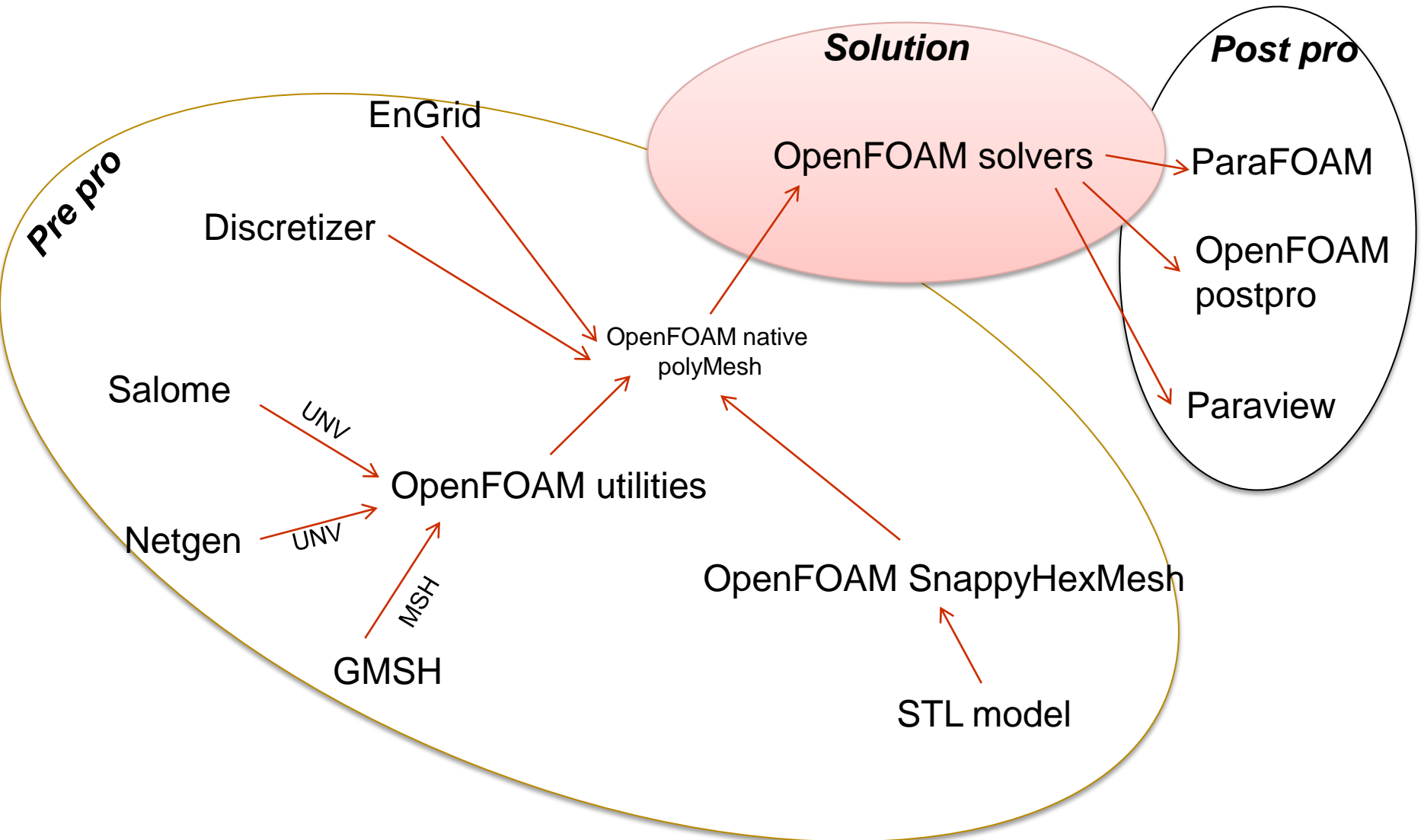


# Other workflows: Code-Saturne

CAD + Meshing in Salome => MED mesh => Code-Saturne Wizard + GUI =>  
Code-Saturne Solver (MPI) => Post pro in Salome or Paraview

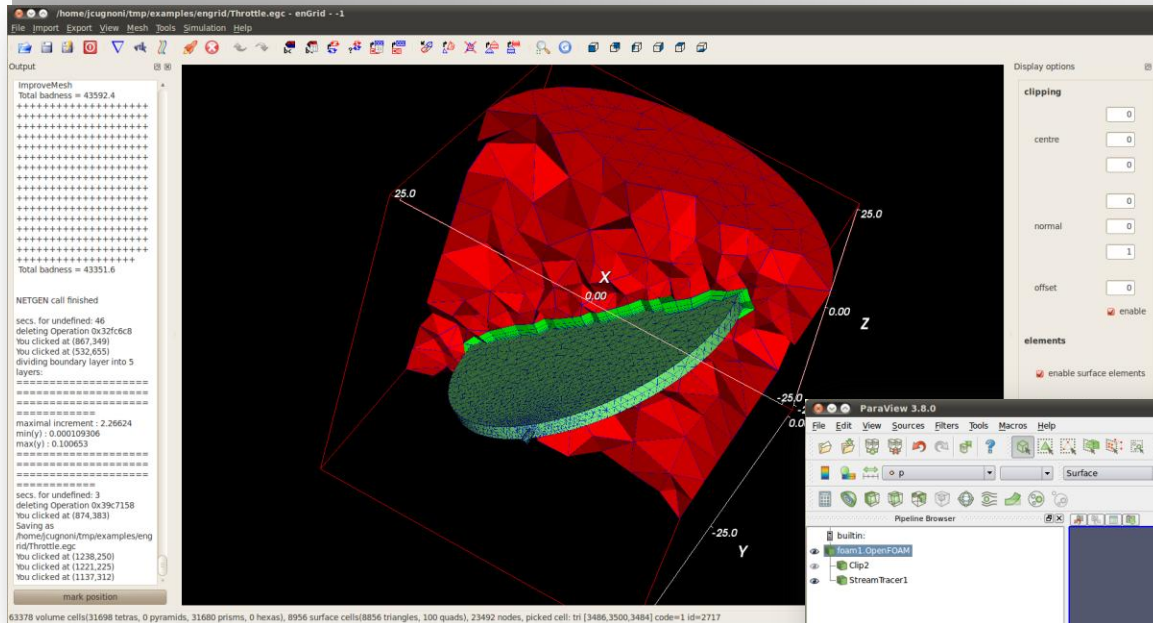


# OpenFOAM Workflow for CFD



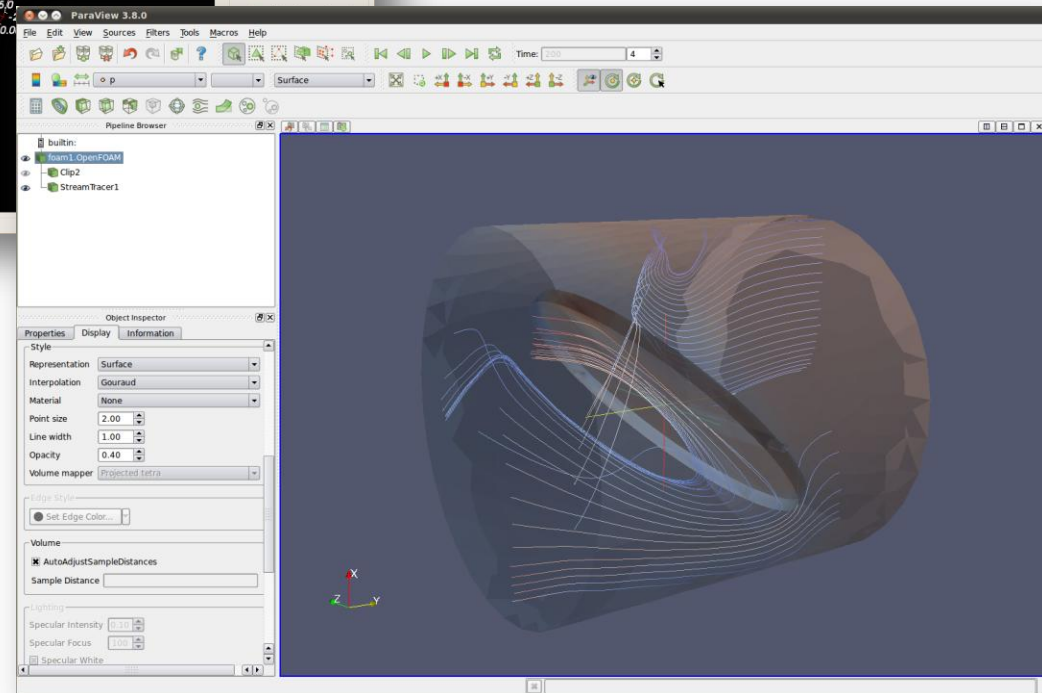


# Example: EnGrid – OpenFOAM (CFD)- Paraview



Boitier papillon, CFD

EnGrid:  
Maillage mixte prisme/tetra  
Prepro OpenFOAM

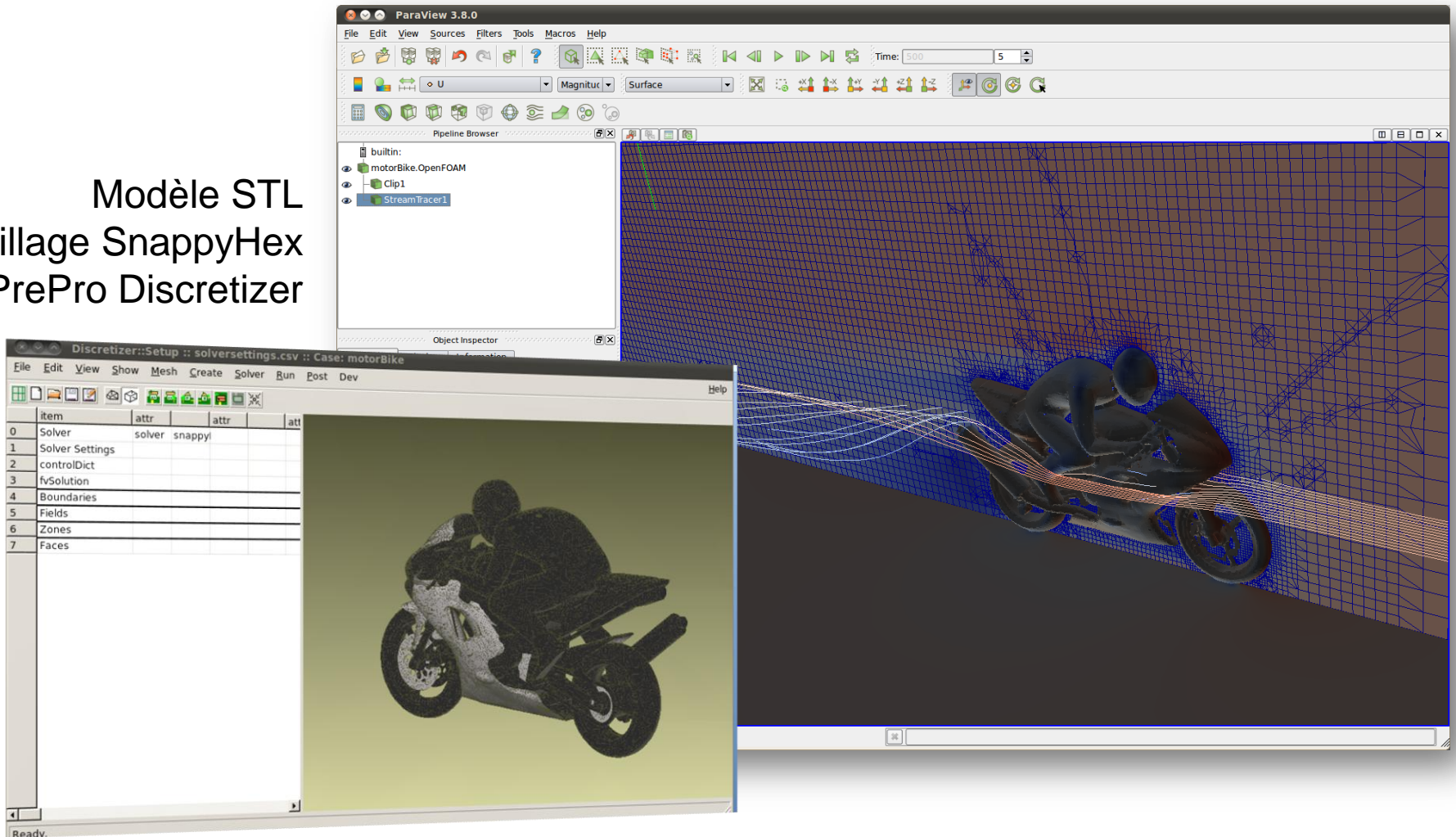


OpenFOAM:  
Solveur SimpleFOAM  
Stationnaire, turbulent, incompressible

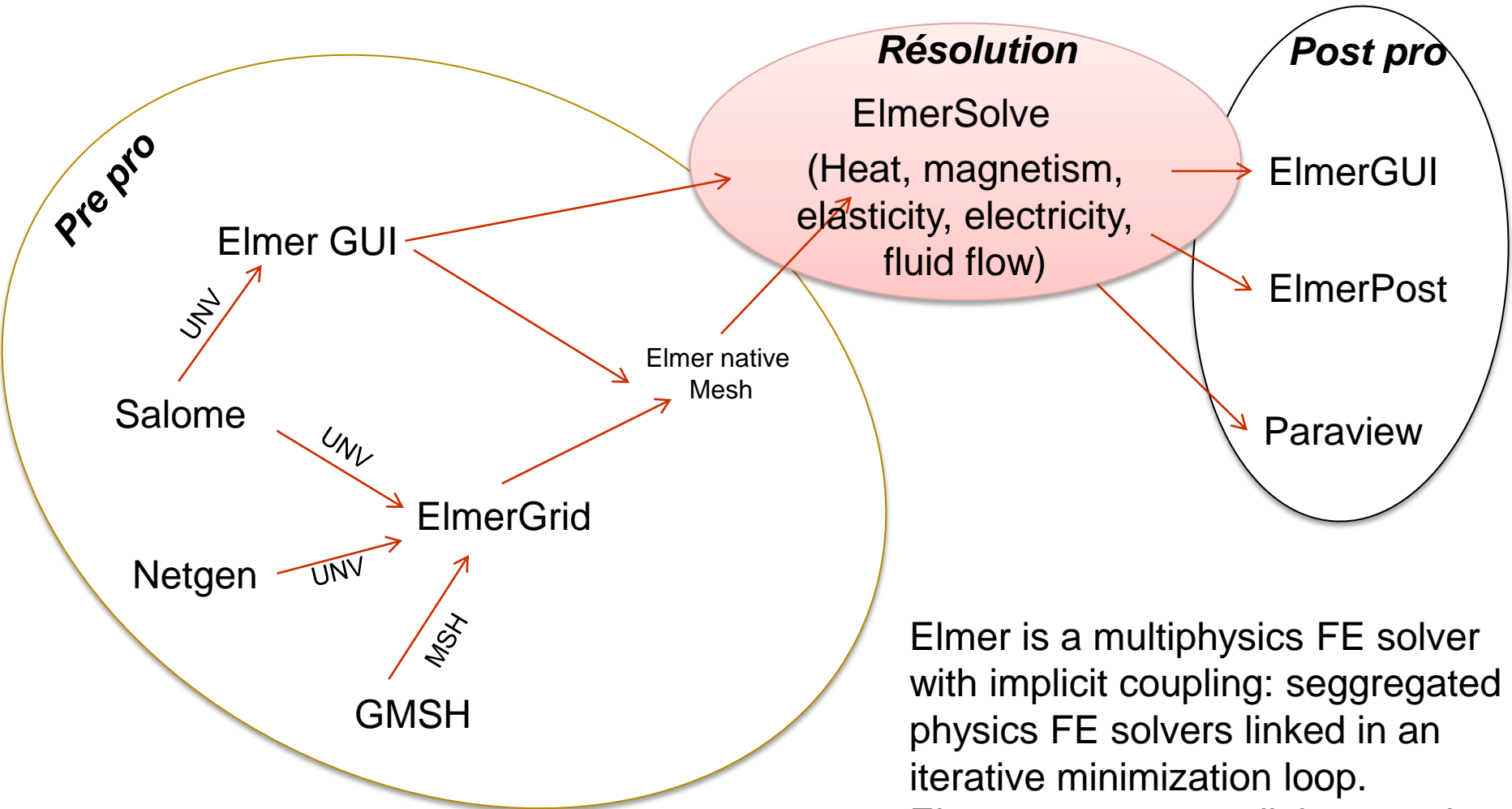
ParaFOAM:  
Post-traitement / visualisation

# Exemple: Discretizer::Setup – SnappyHexMesh - OpenFOAM - Paraview

Modèle STL  
Maillage SnappyHex  
PrePro Discretizer



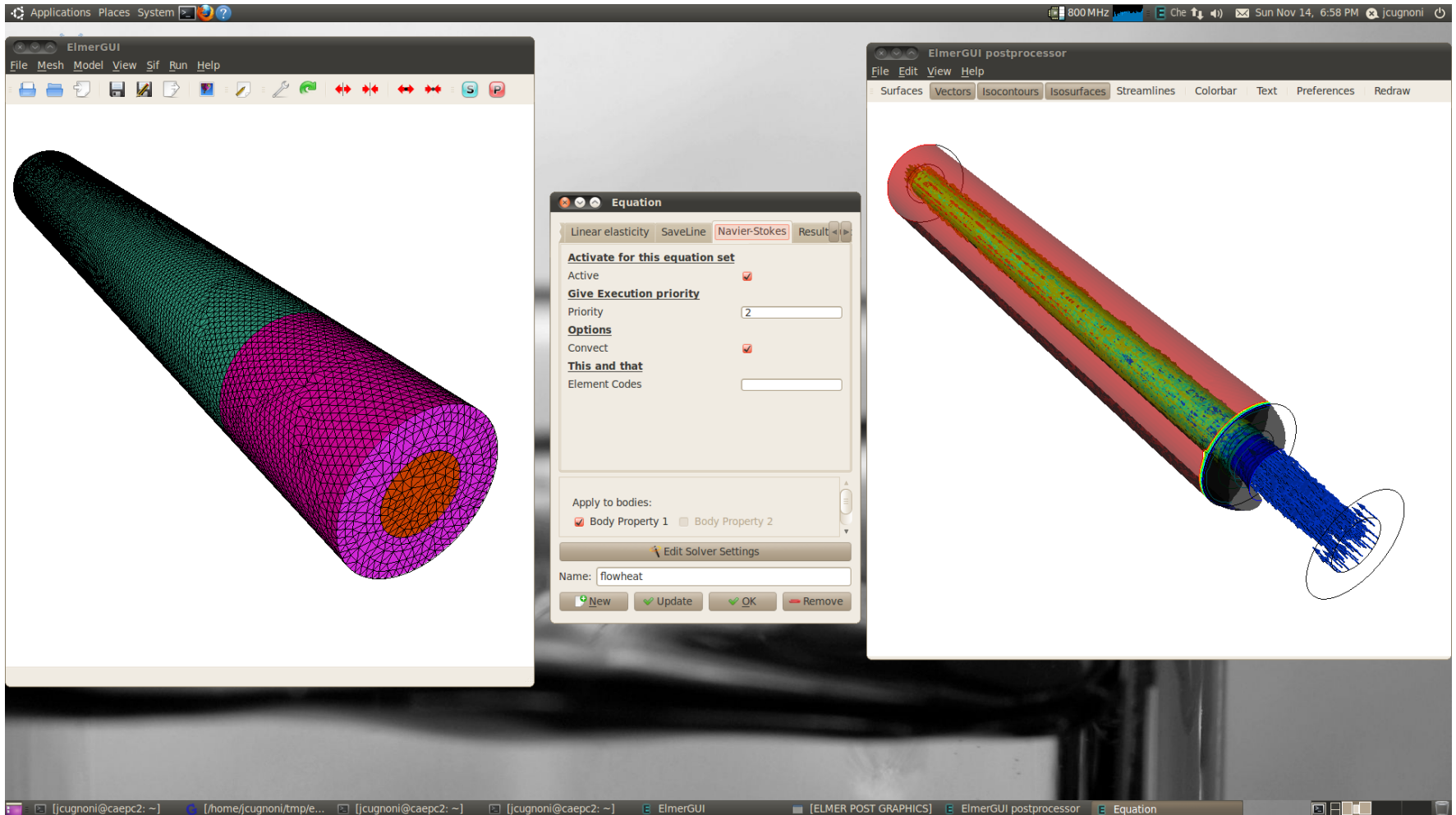
# Multiphysics simulation workflow with Elmer (FE)



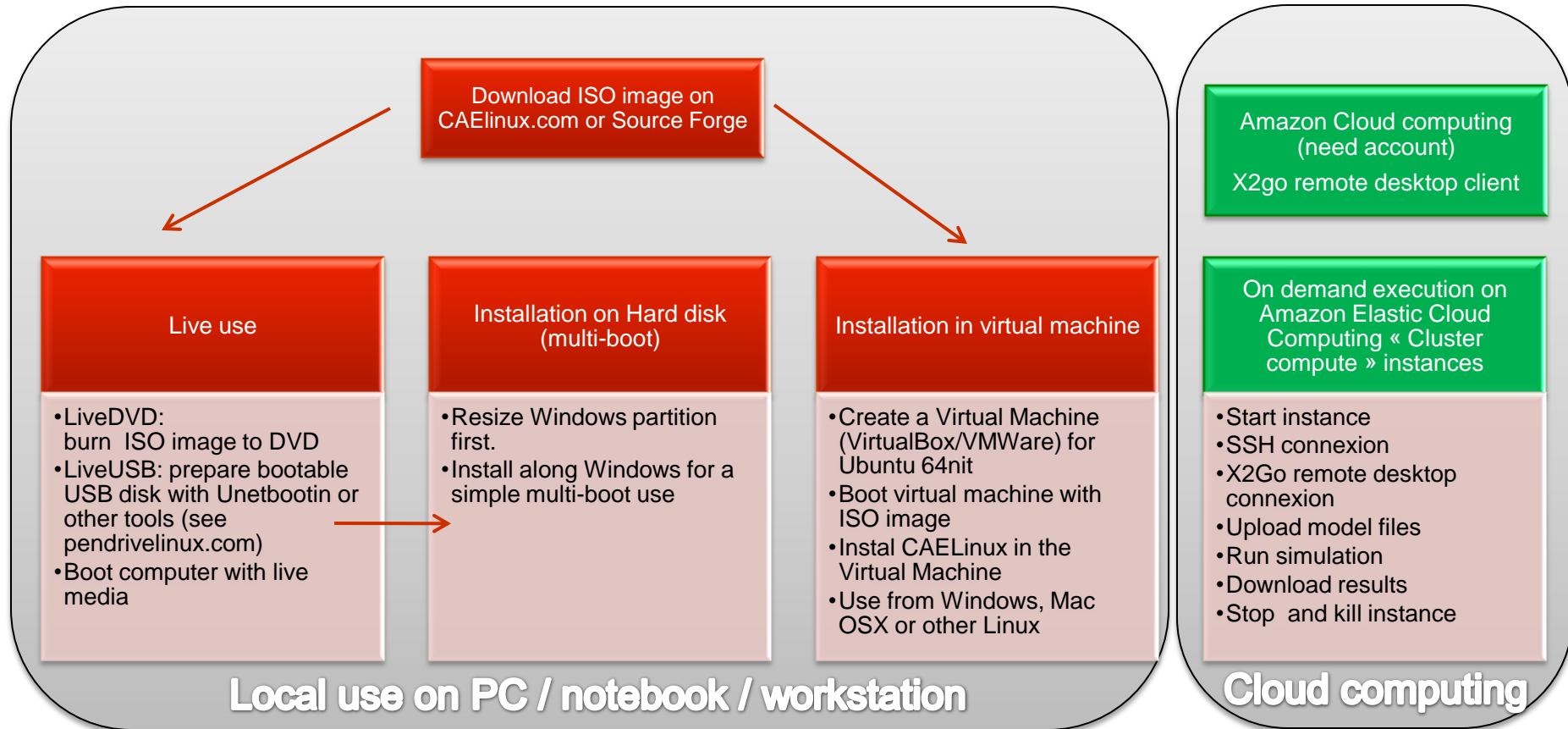
Elmer is a multiphysics FE solver with implicit coupling: segregated physics FE solvers linked in an iterative minimization loop. Elmer supports parallel computing through OpenMPI.

# Exemple: Salome (unv) - ElmerGUI –Elmer

Echangeur de chaleur tubulaire: Navier-Stokes + Transfert Chaleur (cond. + conv.)

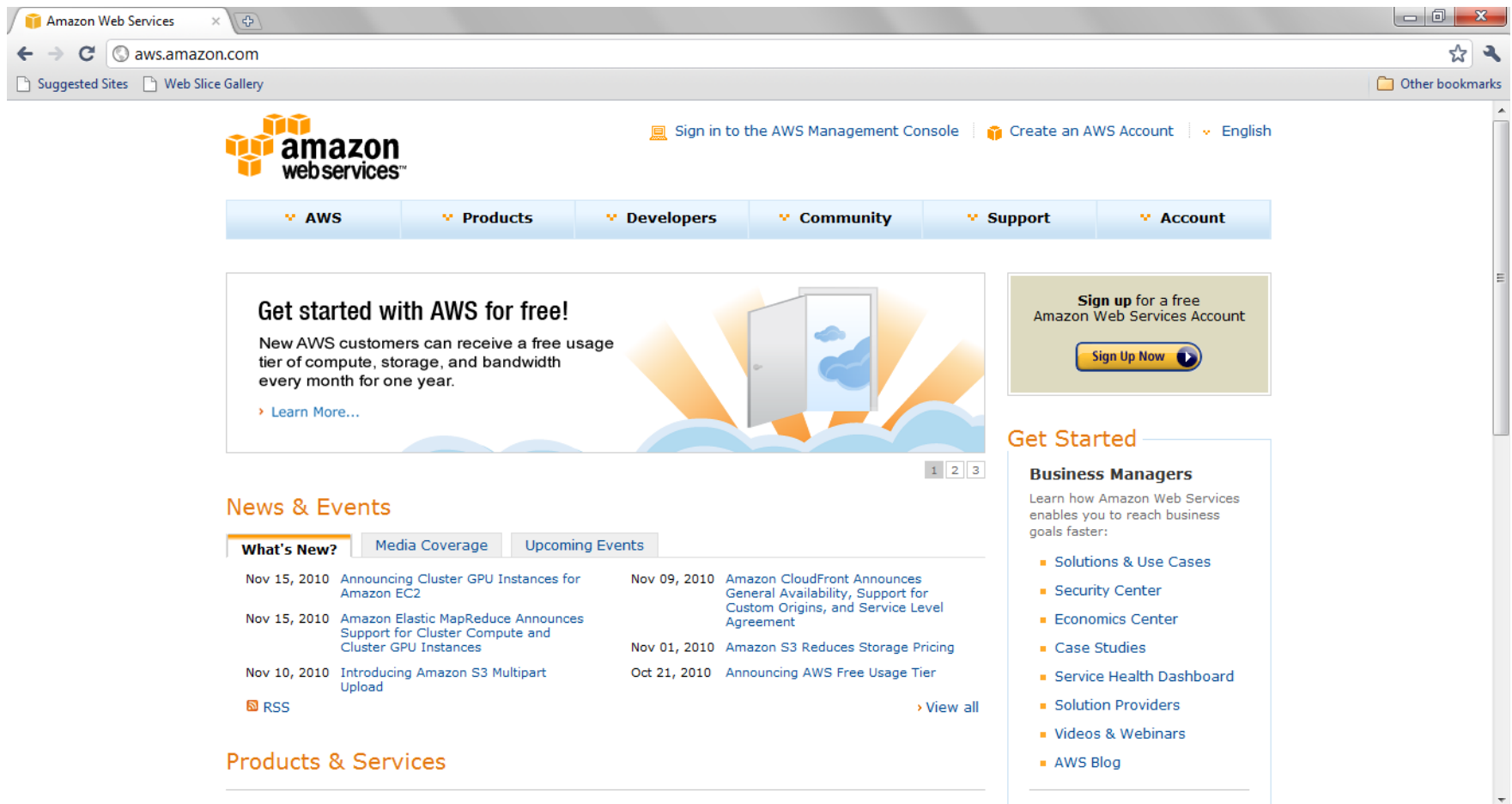


# How to deploy / use CAELinux ?



# CAELinux in the Cloud on Amazon EC2

- o Start instances of CAELinux from aws.amazon.com



The screenshot shows the AWS website homepage in a browser window. The browser's address bar displays 'aws.amazon.com'. The page features the AWS logo, navigation links for 'Sign in to the AWS Management Console' and 'Create an AWS Account', and a language selector set to 'English'. A main navigation bar includes links for 'AWS', 'Products', 'Developers', 'Community', 'Support', and 'Account'. A prominent banner advertises 'Get started with AWS for free!', stating that new customers receive a free usage tier of compute, storage, and bandwidth every month for one year. A 'Sign up for a free Amazon Web Services Account' button is also visible. Below the banner, there is a 'News & Events' section with tabs for 'What's New?', 'Media Coverage', and 'Upcoming Events'. The 'What's New?' tab is active, showing a list of recent announcements from November 2010, including updates on Amazon EC2, Amazon CloudFront, Amazon Elastic MapReduce, Amazon S3, and the AWS Free Usage Tier. A 'View all' link is provided at the end of the list. To the right, a 'Get Started' section titled 'Business Managers' offers various resources such as 'Solutions & Use Cases', 'Security Center', 'Economics Center', 'Case Studies', 'Service Health Dashboard', 'Solution Providers', 'Videos & Webinars', and the 'AWS Blog'.

# CAELinux in the Cloud: remote desktop

The screenshot displays a remote desktop environment. On the left, the AWS Management Console is open, showing the Amazon EC2 dashboard for the EU West region. The main window is SALOME 5.1.3, a CAD/CAE software, displaying a 3D mesh model of a piston. The Object Browser on the left lists various components like Geometry, Mesh, Hypotheses, Algorithms, Mesh\_1, Aster, linear-static, Post-Pro, MAIL, and Presentations. The 3D viewer shows the piston model with a color gradient from blue to red, indicating stress or temperature distribution. A red arrow points to a specific location on the model. The desktop background is Ubuntu, and the system tray shows the date and time as Wed 17 Nov, 2:05 AM. A yellow text box at the bottom of the screenshot reads: "Remote desktop with X2Go Client From Windows/Mac/Linux!!".