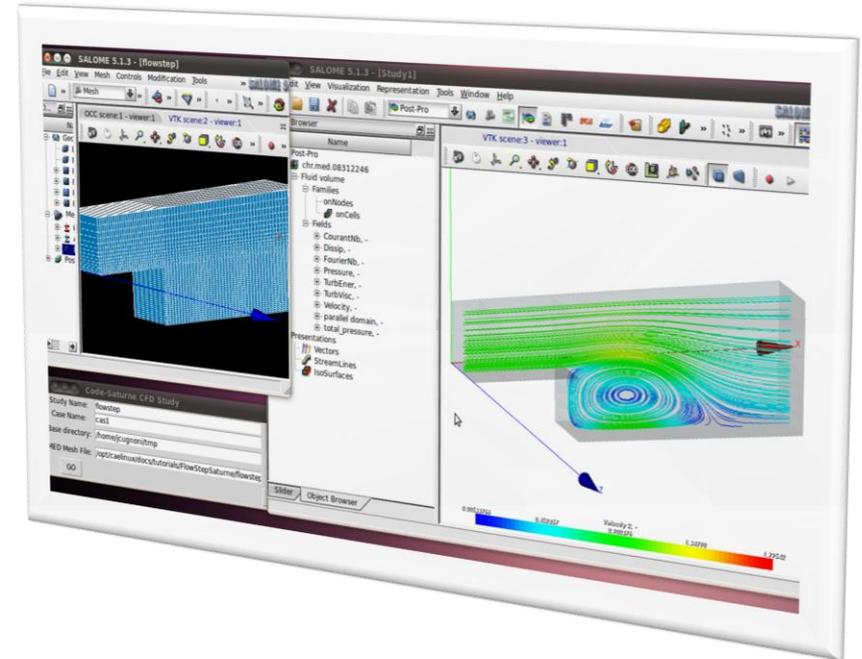
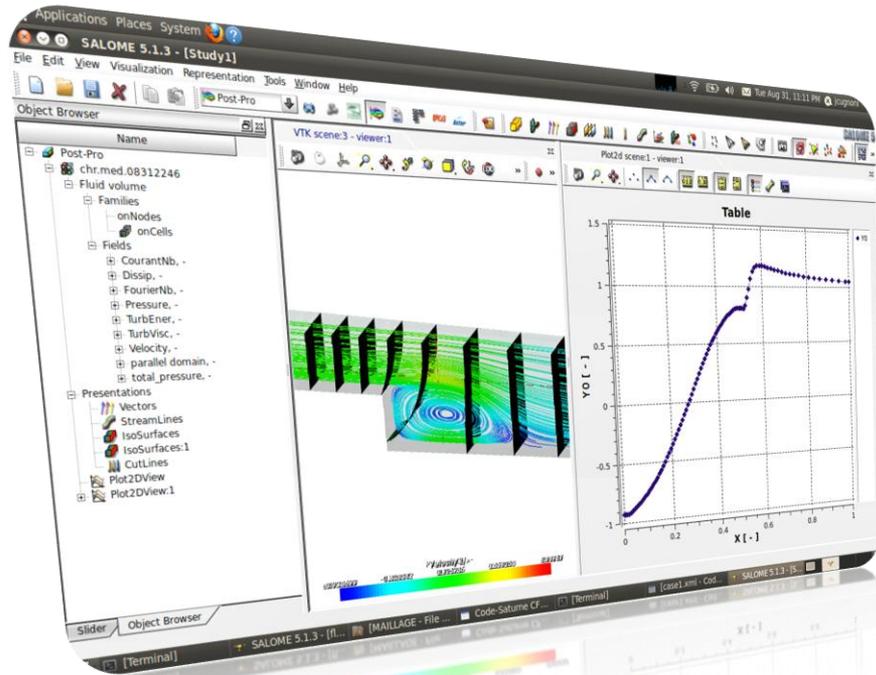


CAELinux : an open source engineering platform



Joël Cugnoni, 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)

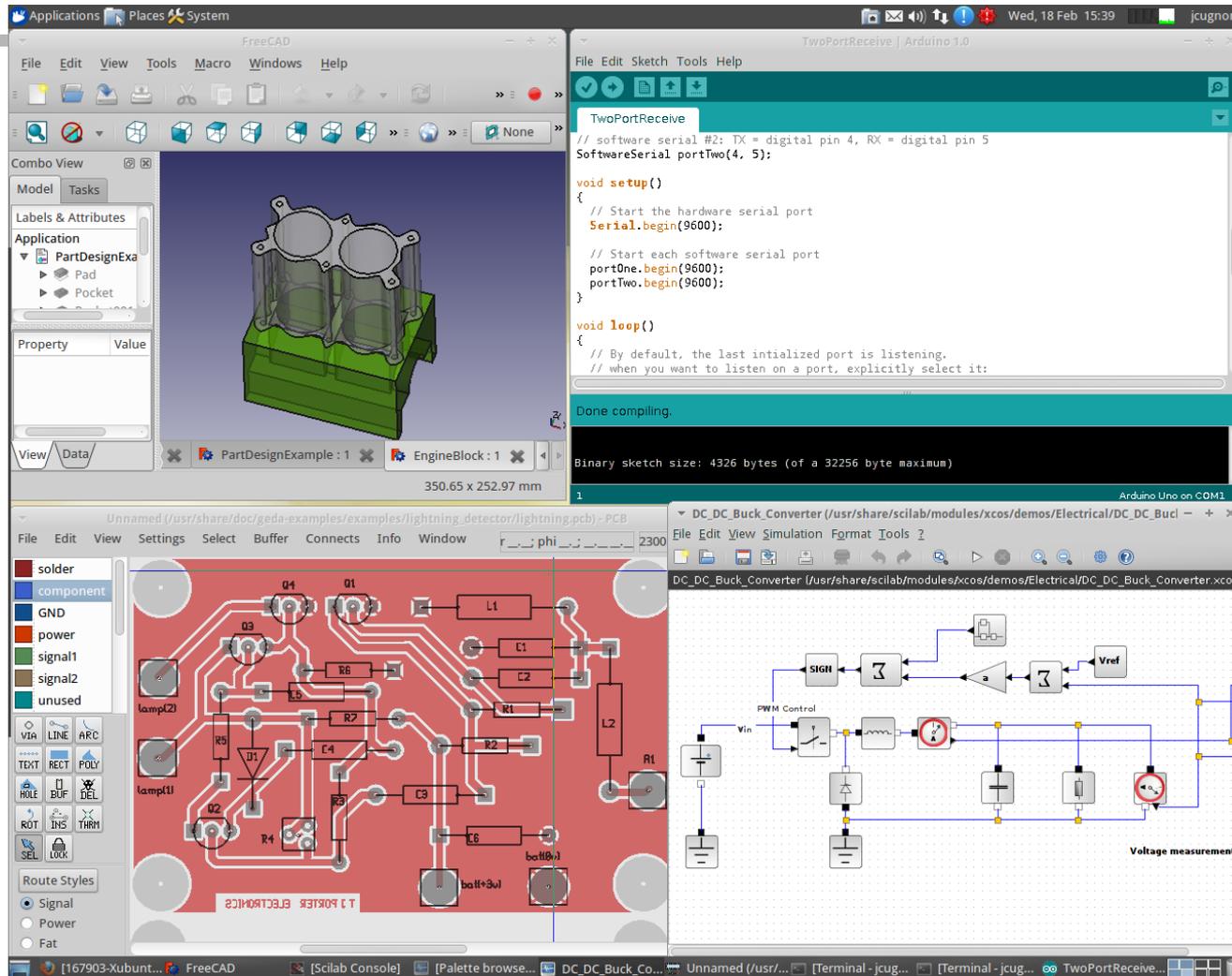


CAELinux: History and present

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 primary 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 central peak. The axes range from -10 to 10 on the x and y axes, and -0.4 to 1 on the z-axis. 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);
```

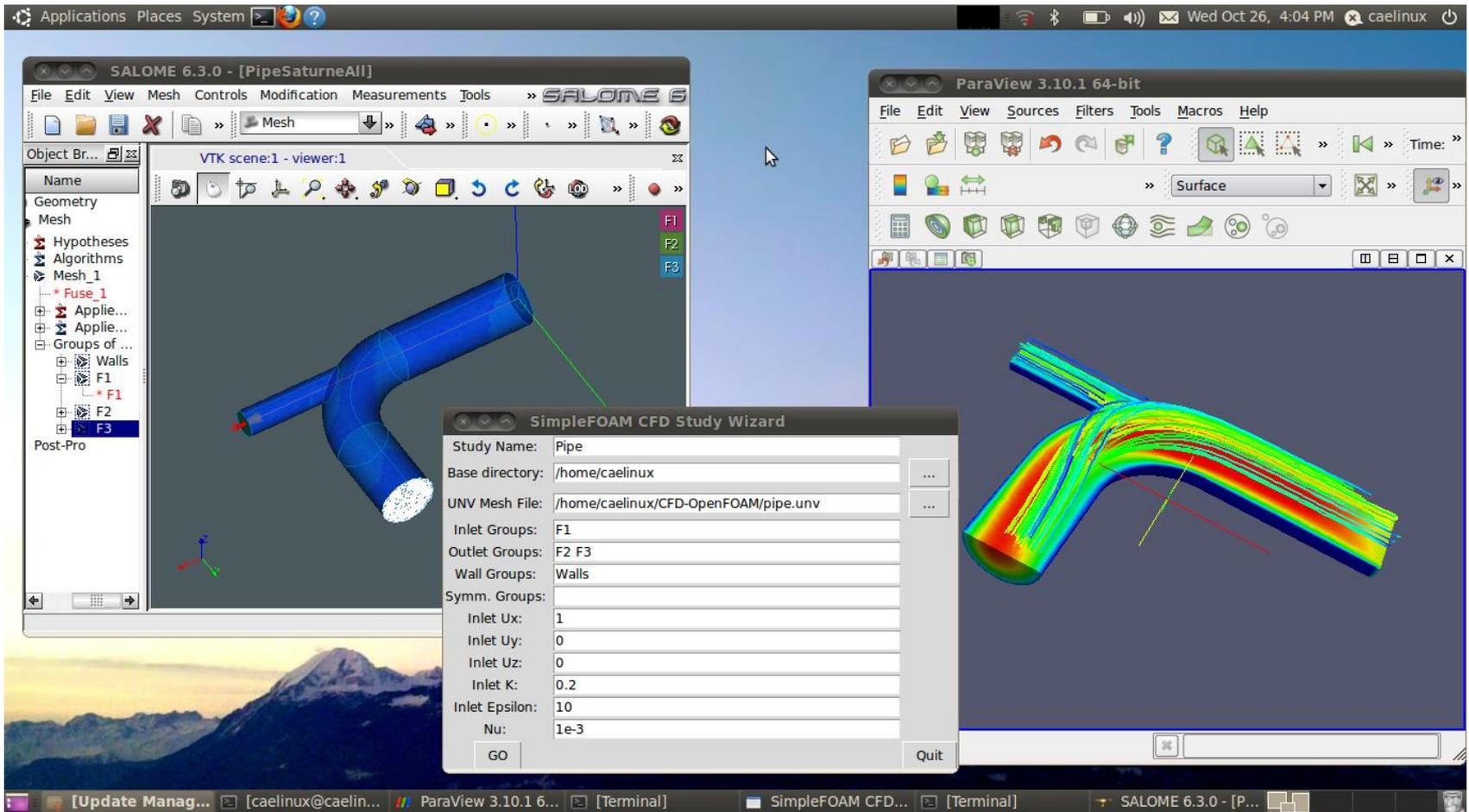
The wxMaxima 0.8.4 [unsaved*] window shows the following code:

```
(%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 $2*(\sqrt{x}+1)-2*\log(\sqrt{x}+1)$ over the interval $x \in [0, 1]$. The plot shows a smooth, increasing curve starting at (0, 2) and ending at (1, 2.6).

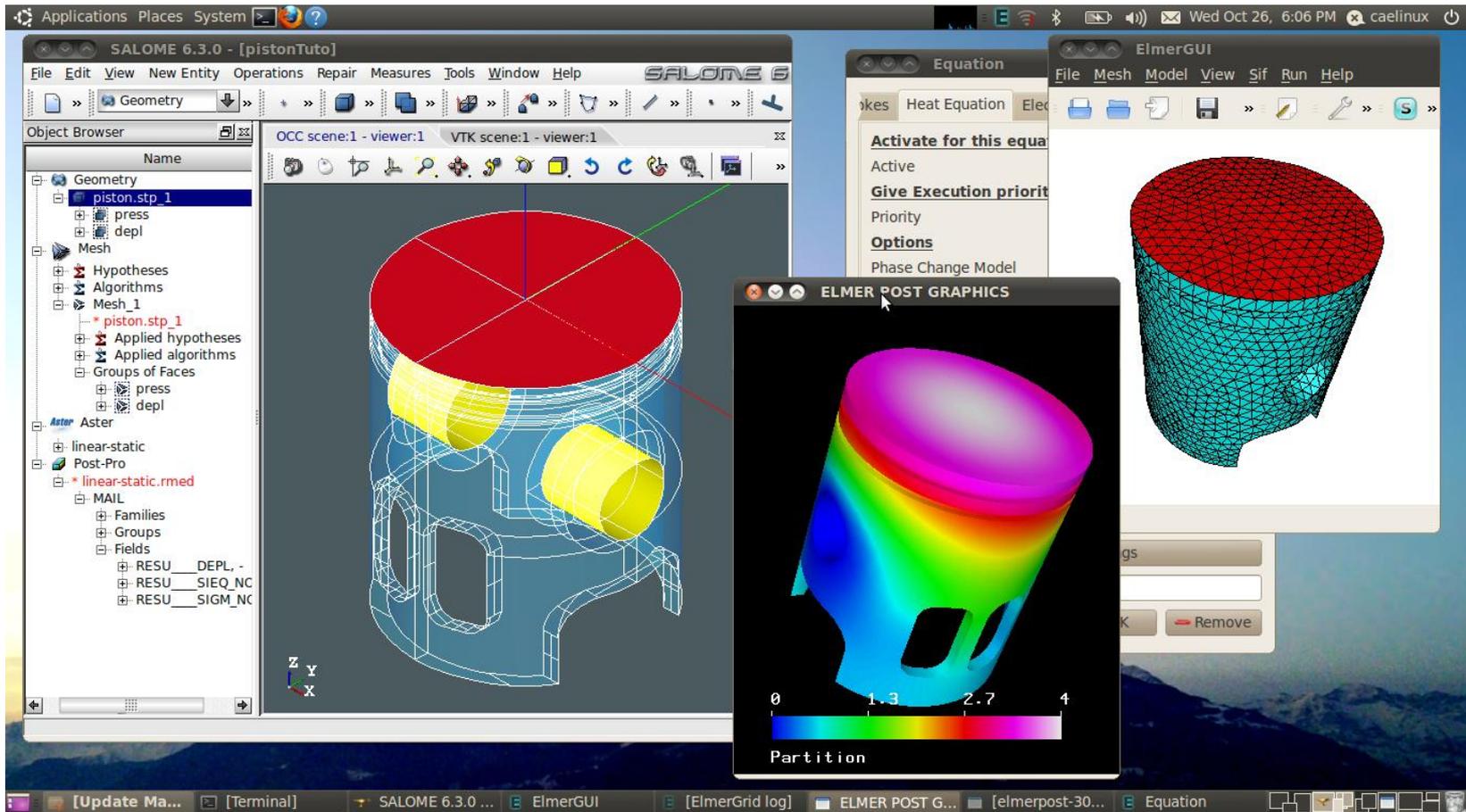
Mathematical modeling and programming: Octave, Maxima, R, Python/Scipy

What can you do with it?



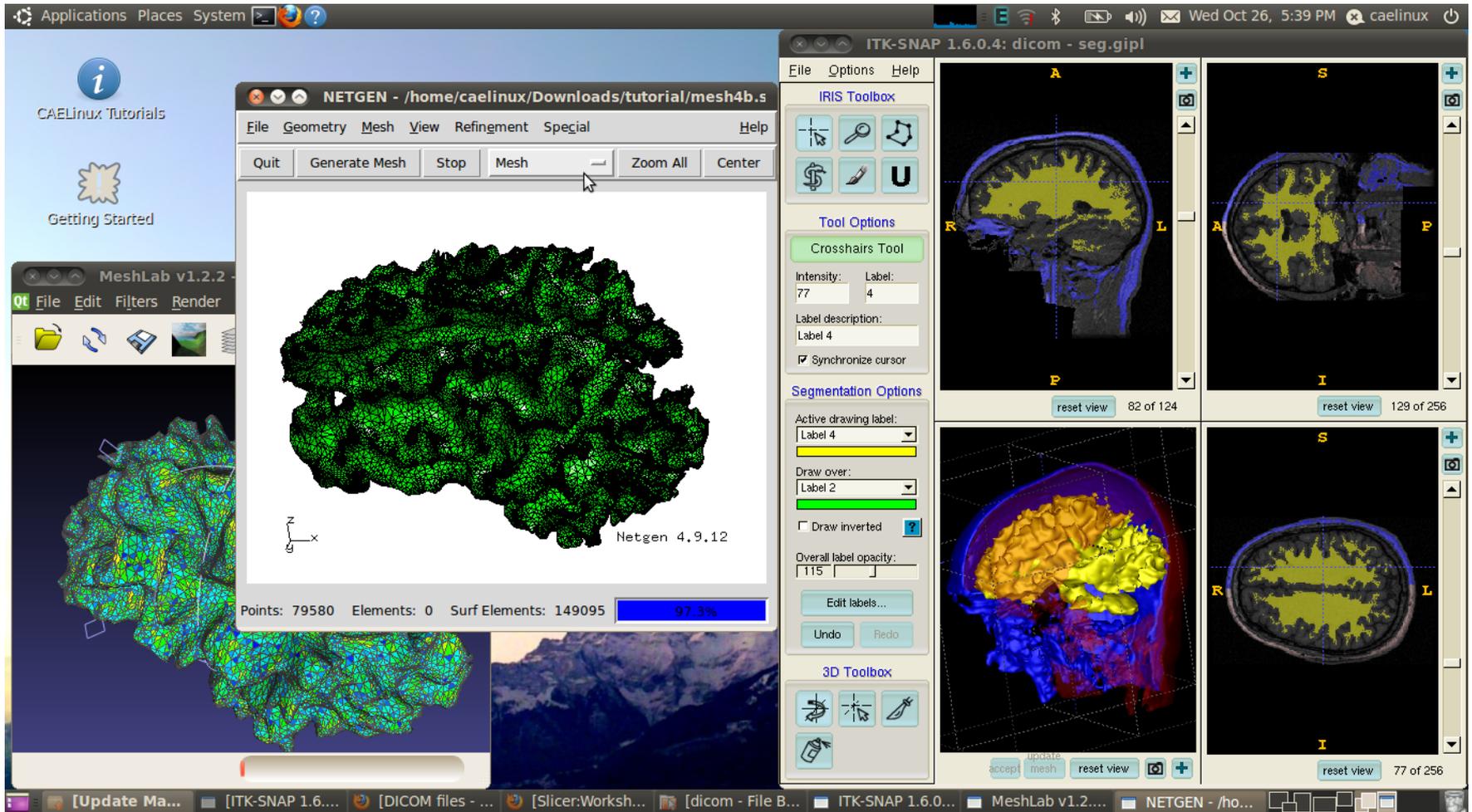
CFD: Salome / OpenFOAM or Code-Saturne

What can you do with it?



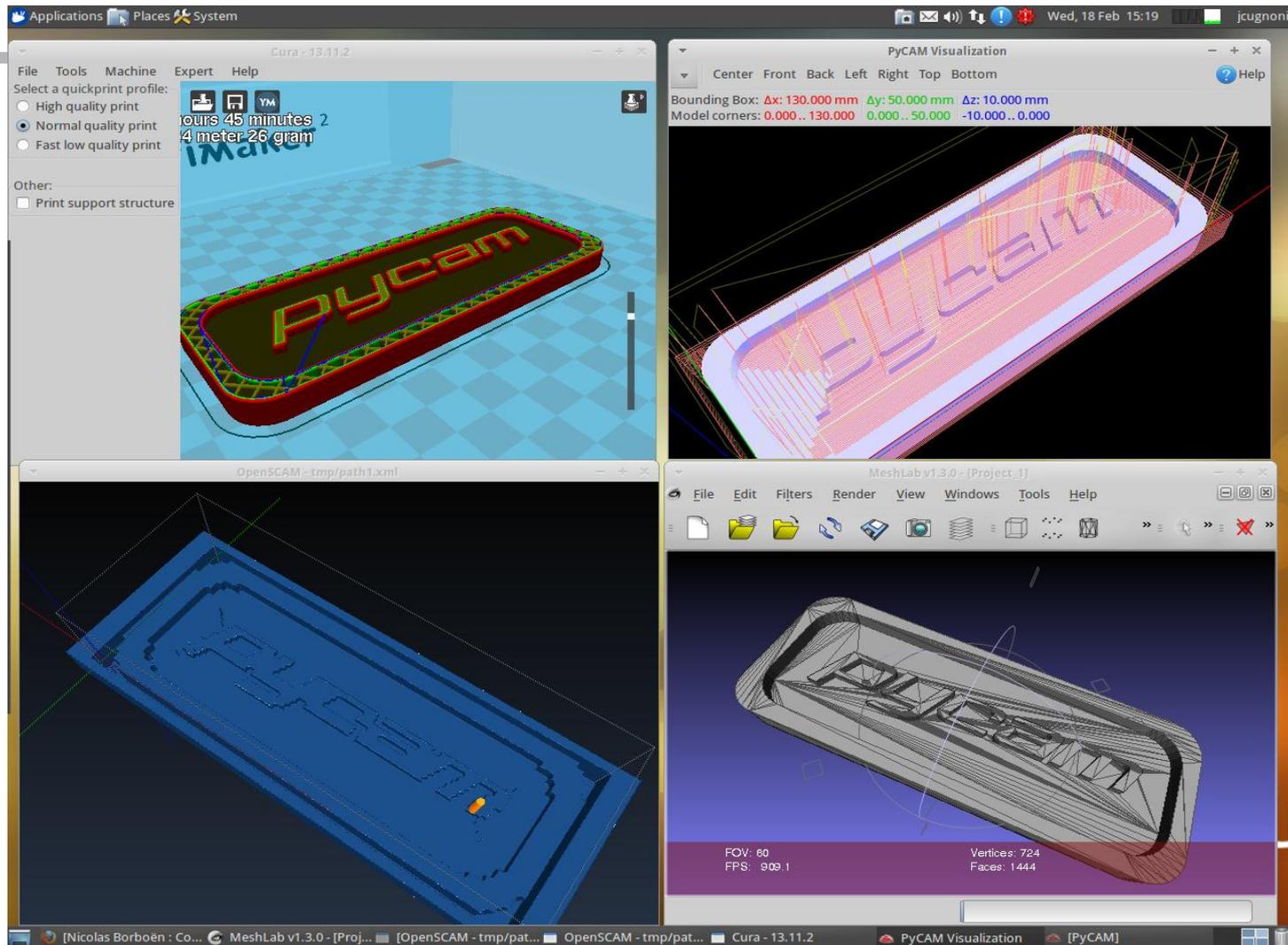
Thermo mechanics: Salome / Elmer or Code-Aster or Calculix

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 ?

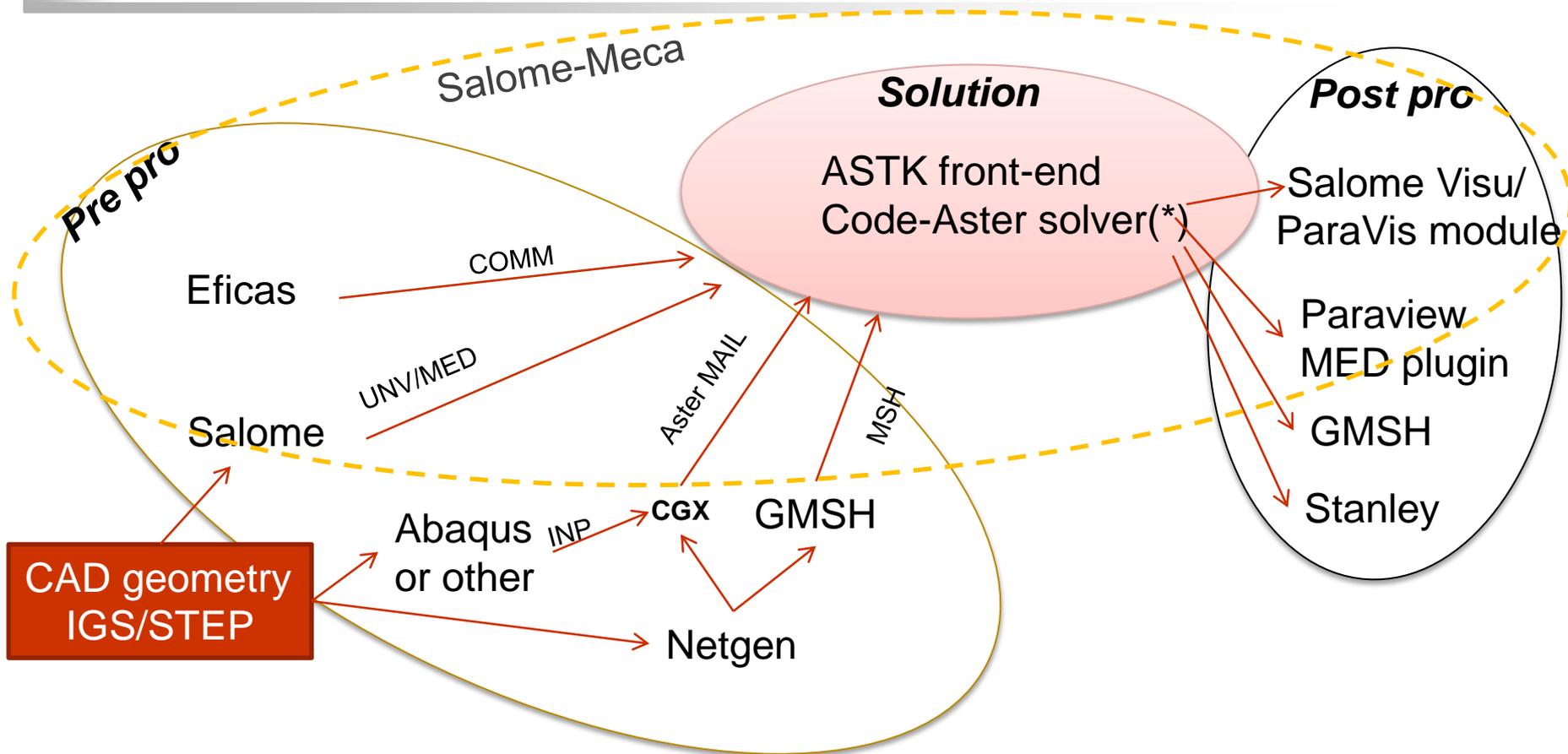
CAE analysis process

- 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



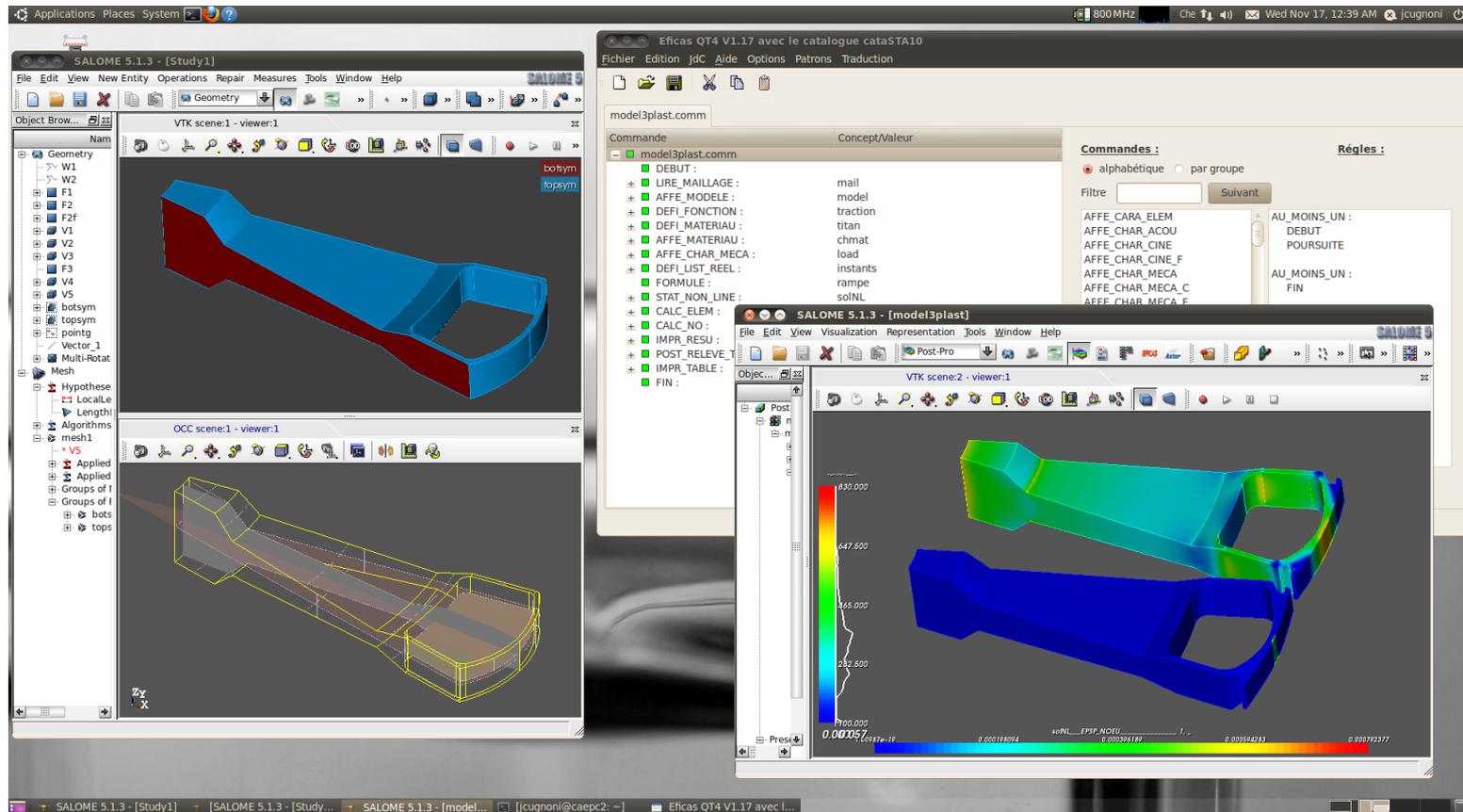
- Two versions of Code-Aster are available in CAELinux:
 - STA and NEW from Salome-Meca with OpenMP parallelism (MULT_FRONT solver)
 - Custom NEW MPI version with PETSC & MUMPS parallel solvers in /opt/aster

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

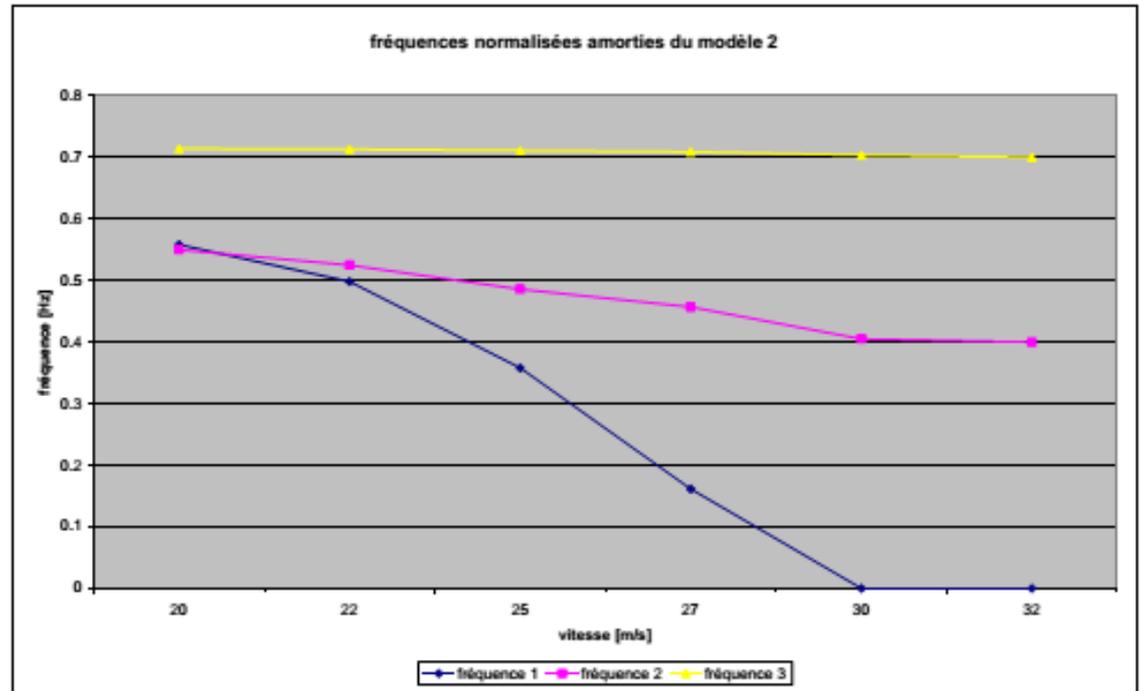
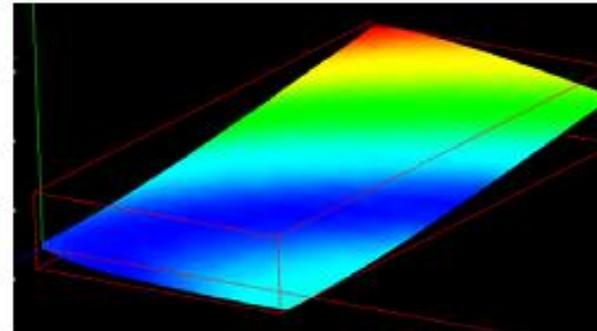
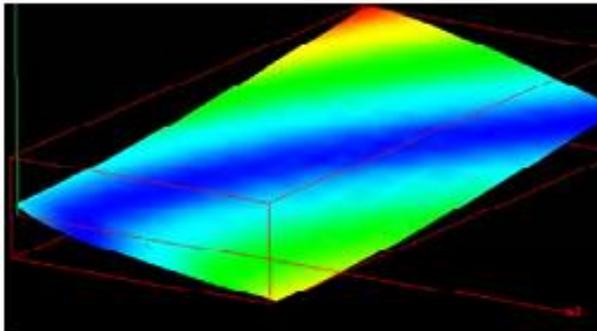
Optimization: Salome + Python + Scipy => Parametric FEA => Code-Aster solver



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

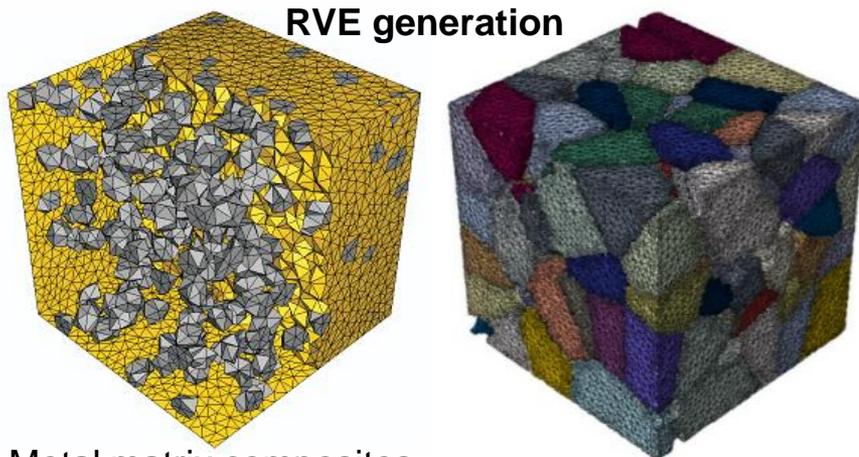


Advantage: unique possibilities of Code-Aster to compute added mass, stiffness and damping from a potential theory.

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

Future work & needs (Research at EPFL)

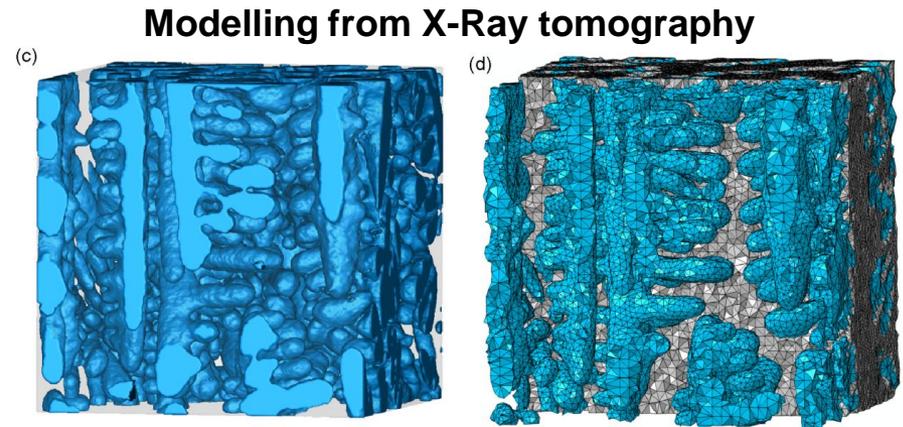
- Migrate homogenization methods developed at LMAF to Code-Aster



RVE generation

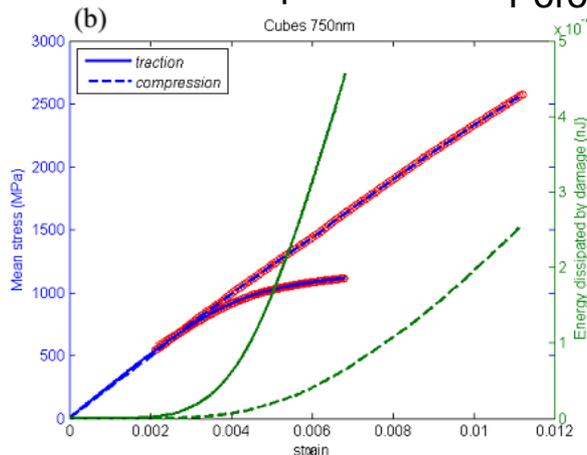
Metal matrix composites

Porous ceramics



Modelling from X-Ray tomography

Alloys (here SnAgCu solder)



Opportunity:

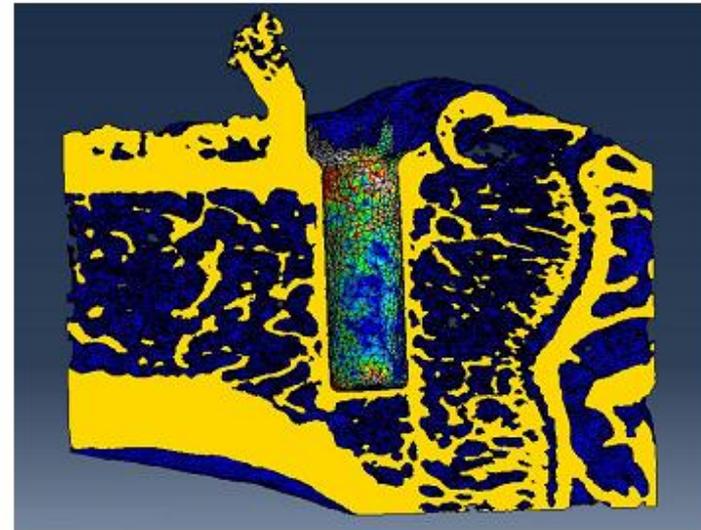
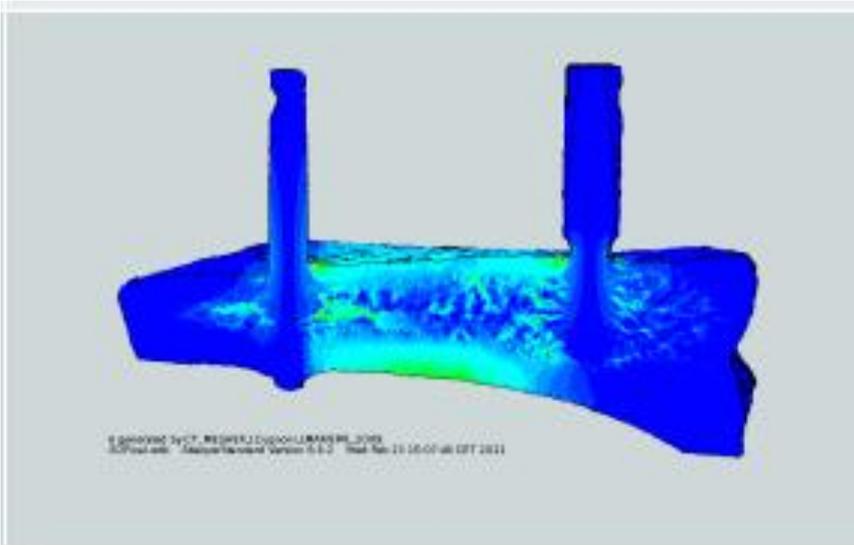
develop an open source homogenization platform (equivalent to Digimat)

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:

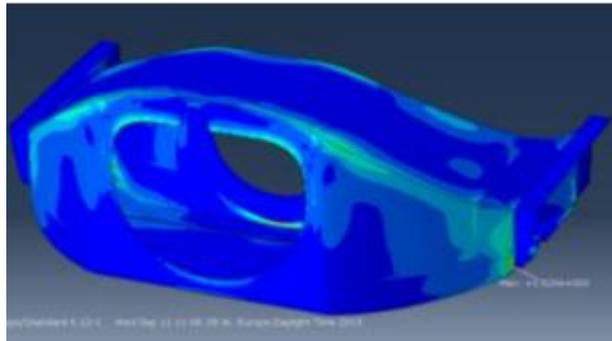
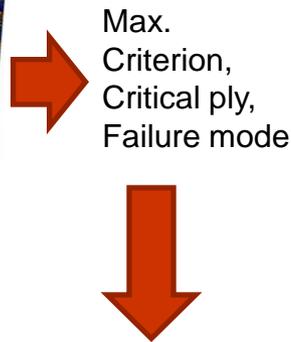
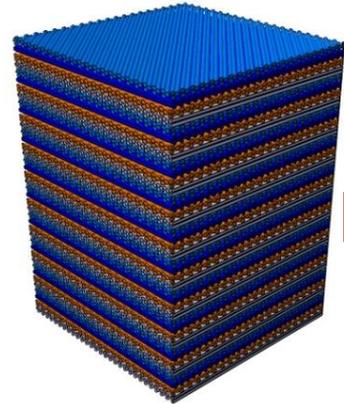
develop an open source platform for biomedical engineering

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

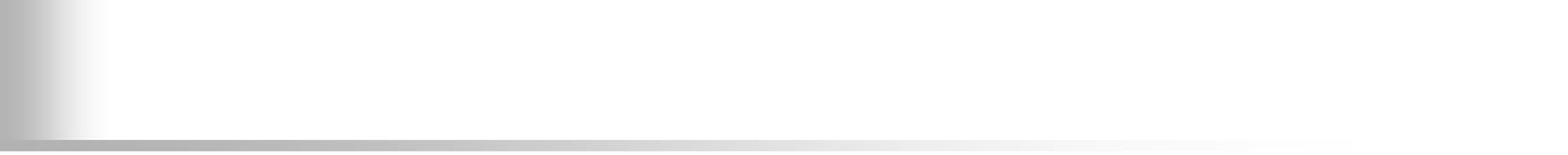
CAELinux: Development and future

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

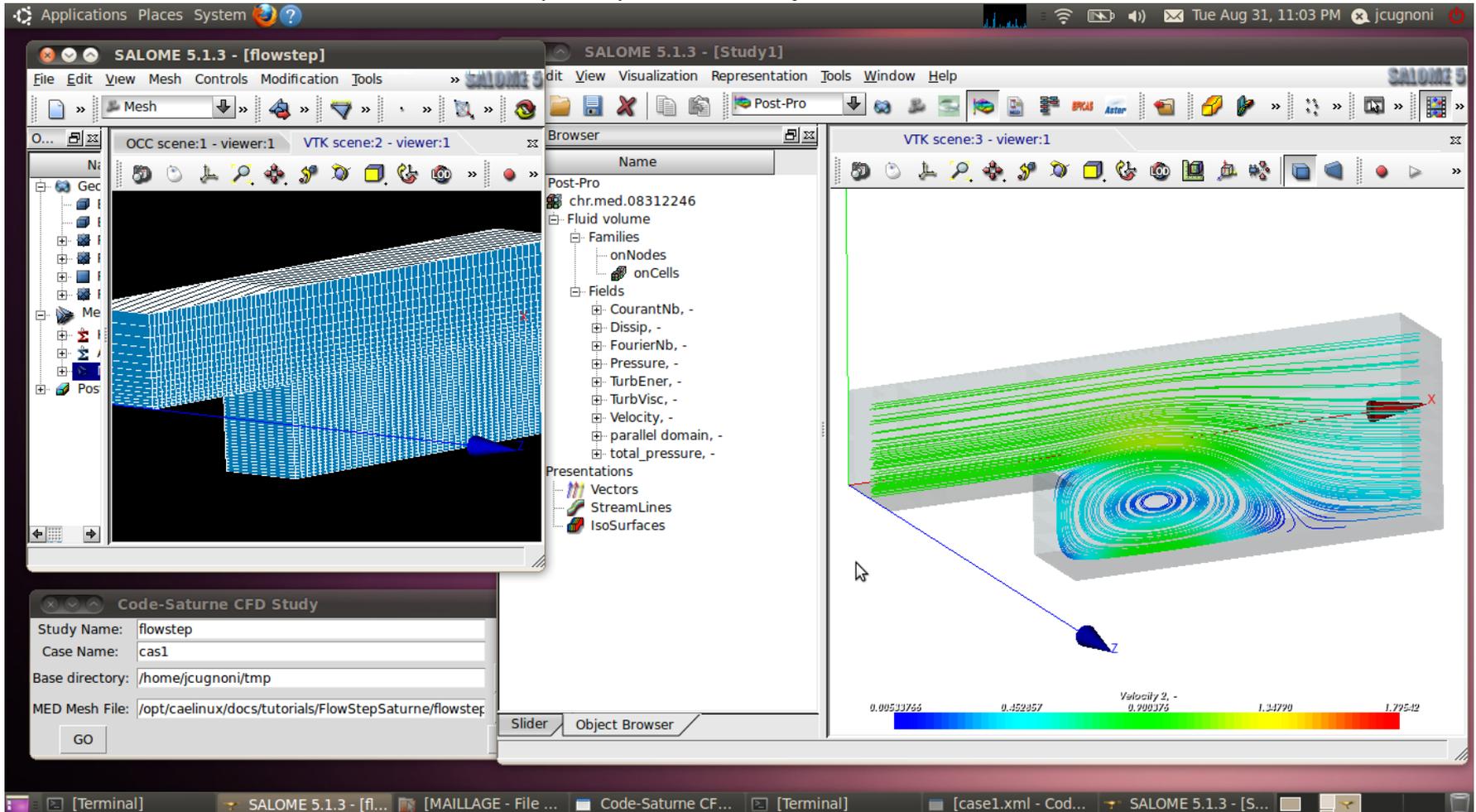
- Development of each package and production / testing of the final distribution is still mostly manual and iterative but ensures good stability.
- Moving to collaborative development is a goal but transition is difficult
- a new release is planned for Q4 2015 based on Ubuntu 14.04.



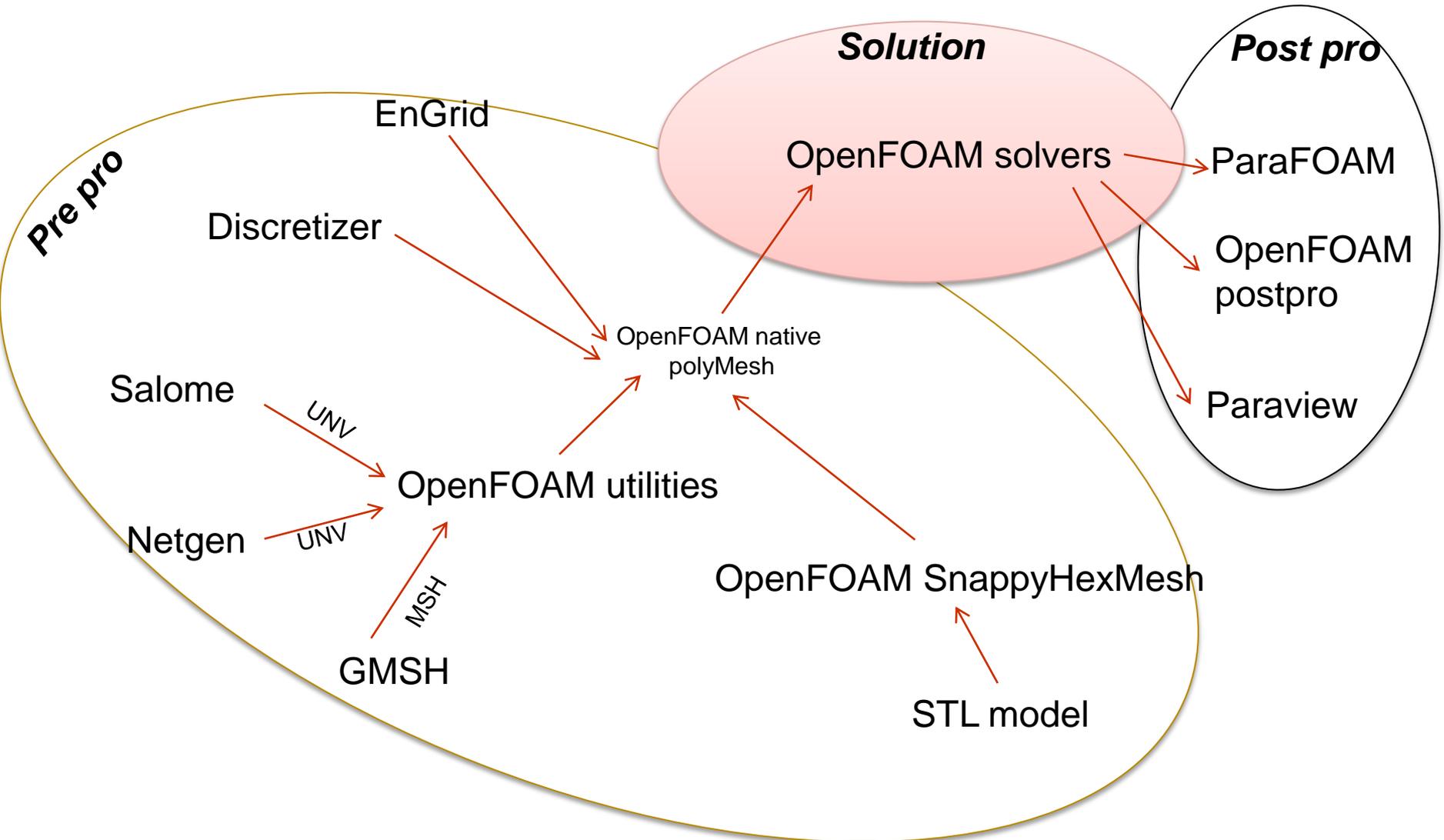
Merci de votre attention !

Other workflows: Code-Saturne

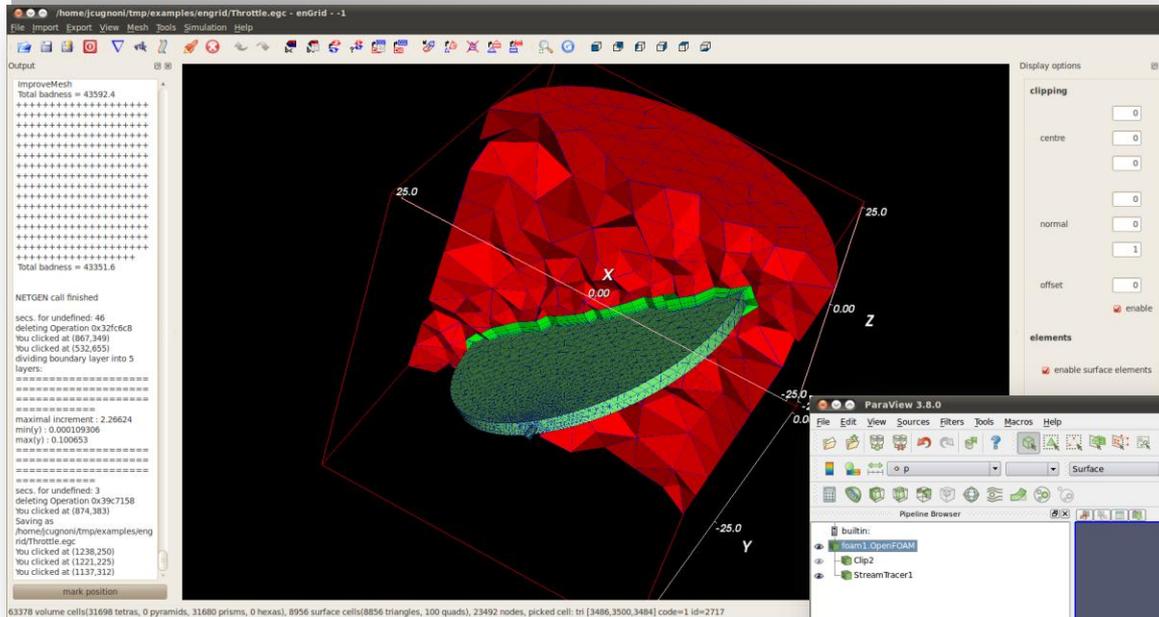
CAD + Meshing in Salome => MED mesh => Code-Saturne Wizard + GUI =>
Code-Saturne Solver (MPI) => Post pro in Salome or Paraview



OpenFOAM Workflow for CFD

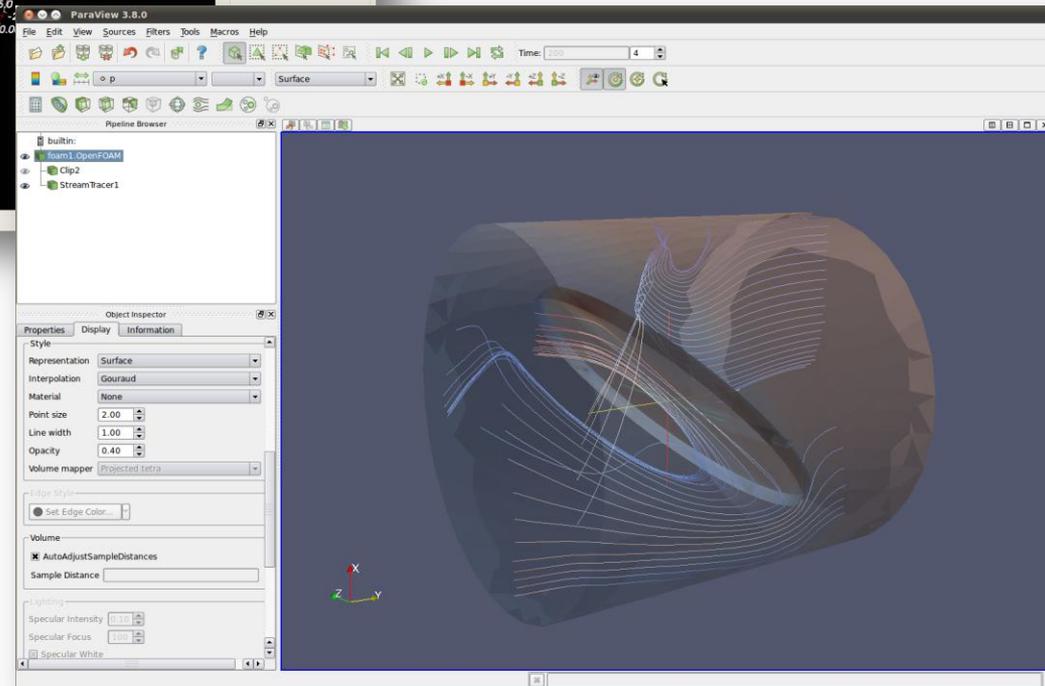


Example: EnGrid – OpenFOAM (CFD)- Paraview



Boitier papillon, CFD

EnGrid:
Maillage mixte prisme/tetra
Prepro OpenFOAM

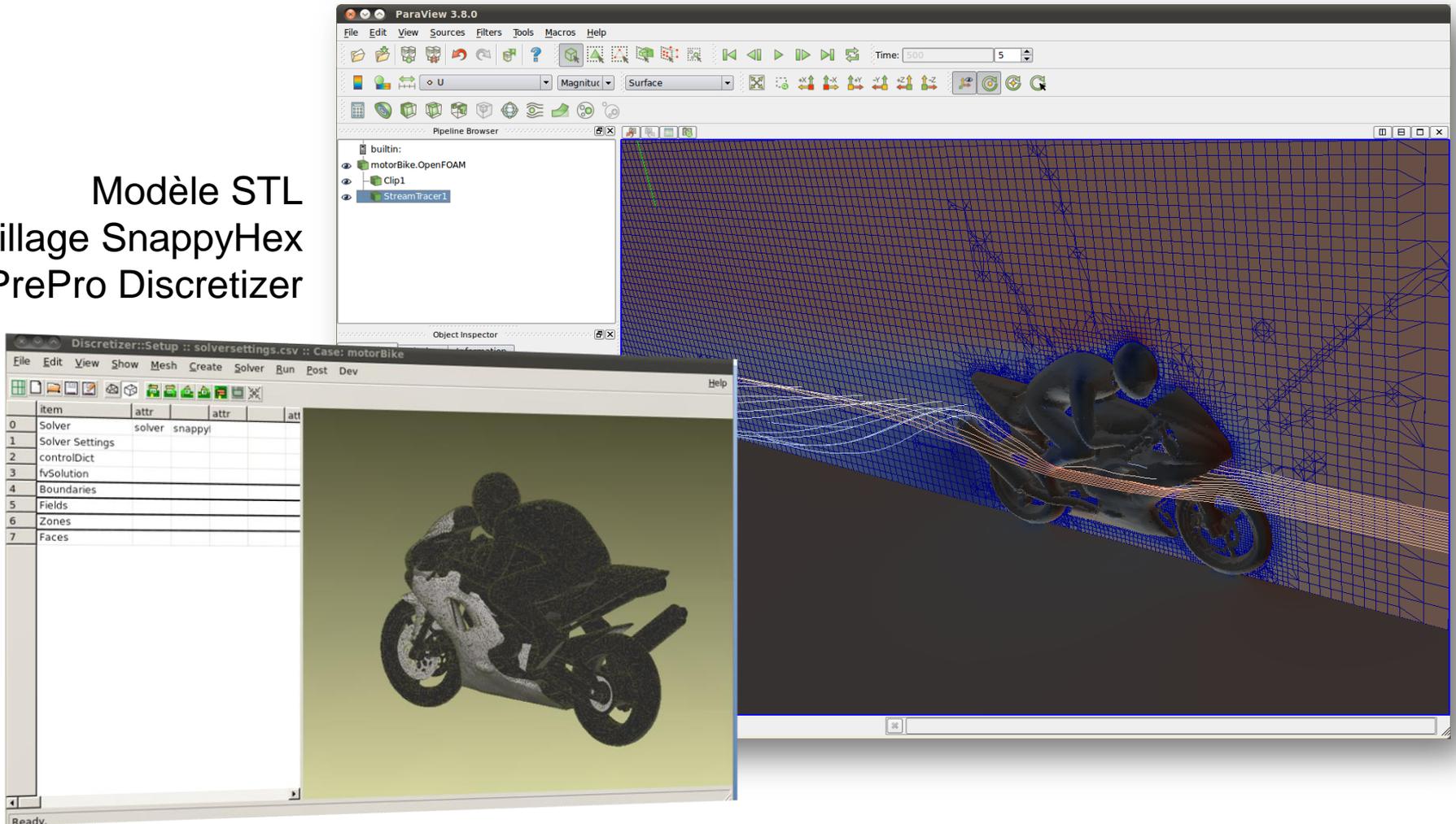


OpenFOAM:
Solveur SimpleFOAM
Stationnaire, turbulent, incompressible

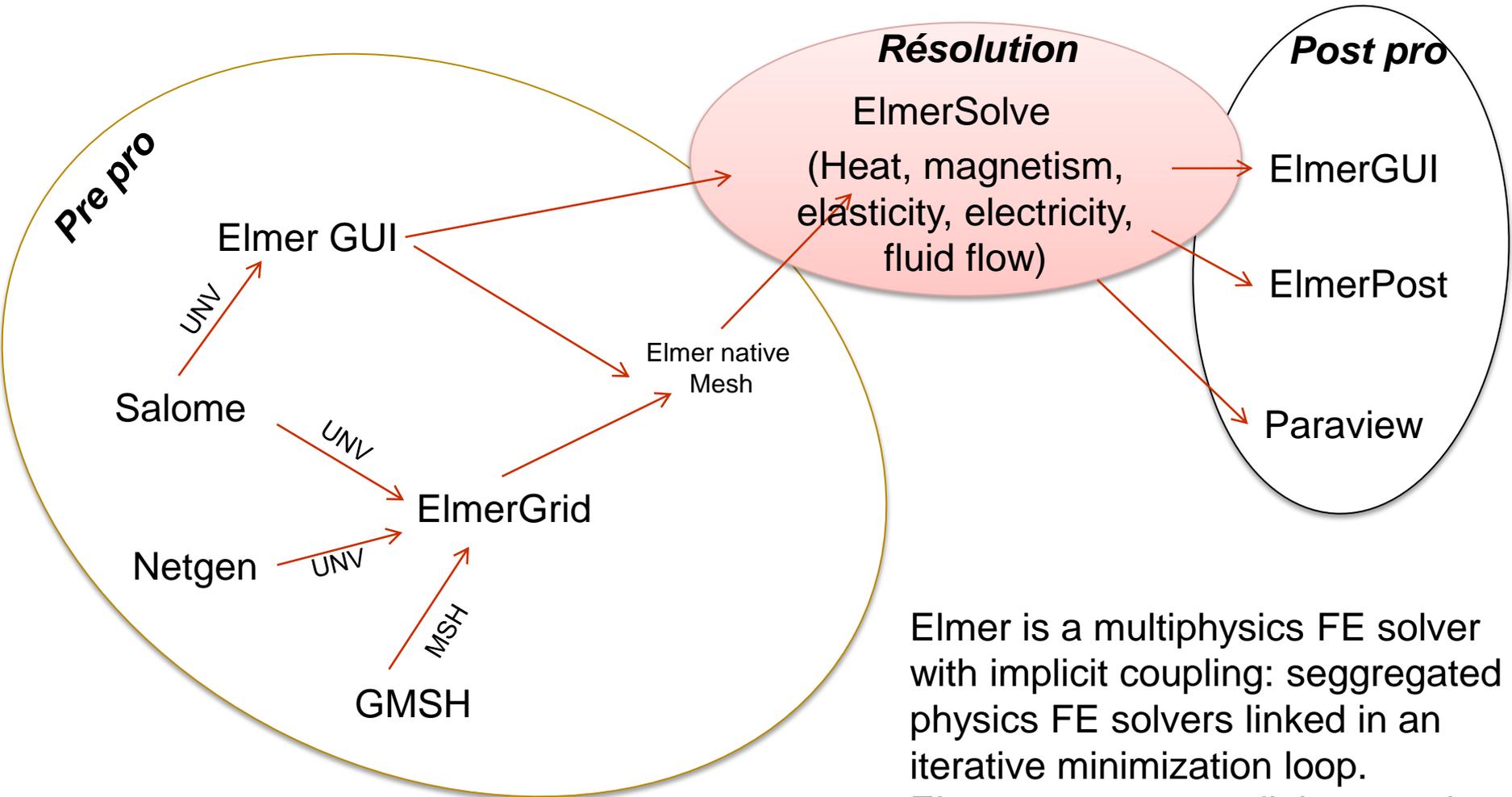
ParaFOAM:
Post-traitement / visualisation

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

Modèle STL
Maillage SnappyHex
PrePro Discretizer



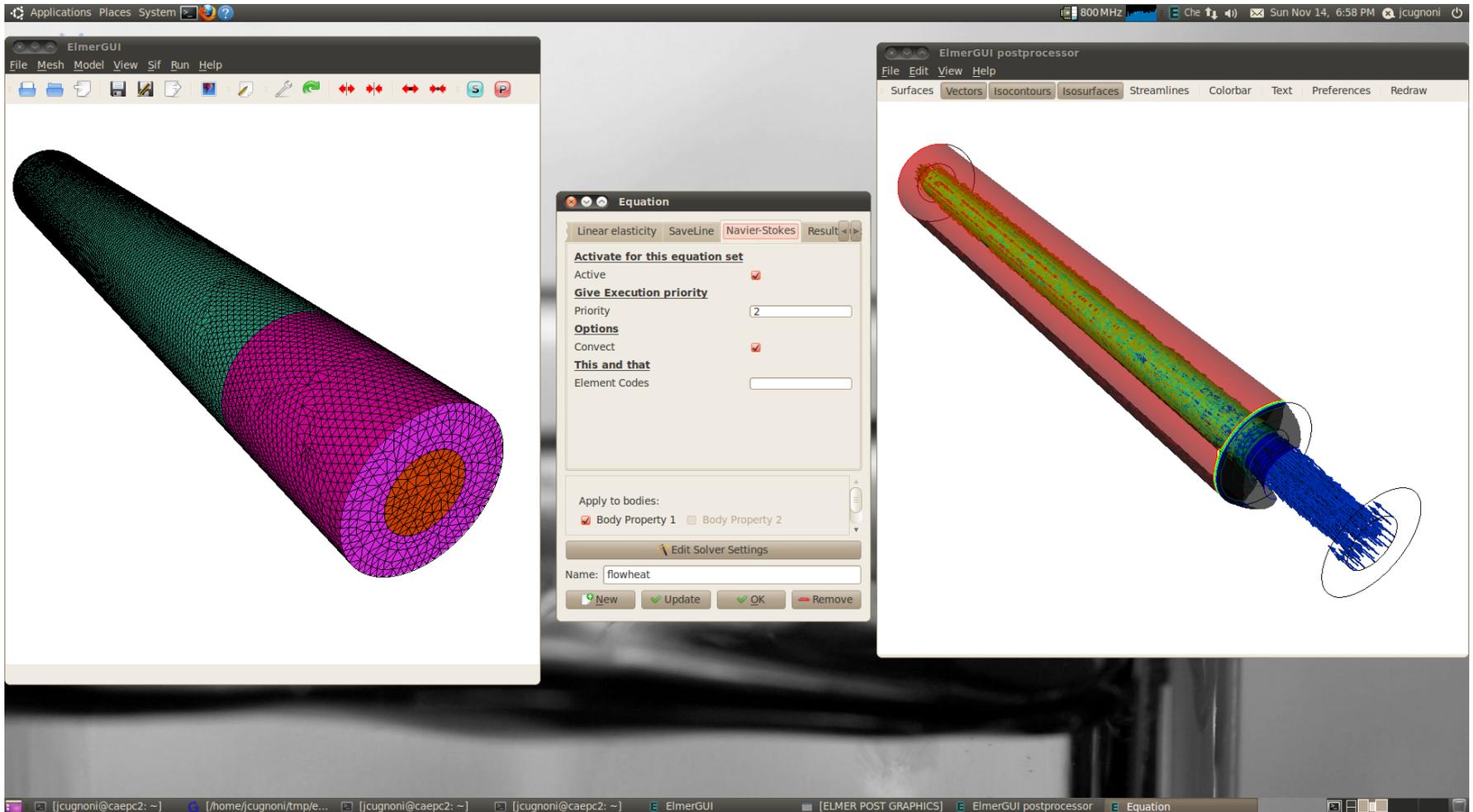
Multiphysics simulation workflow with Elmer (FE)



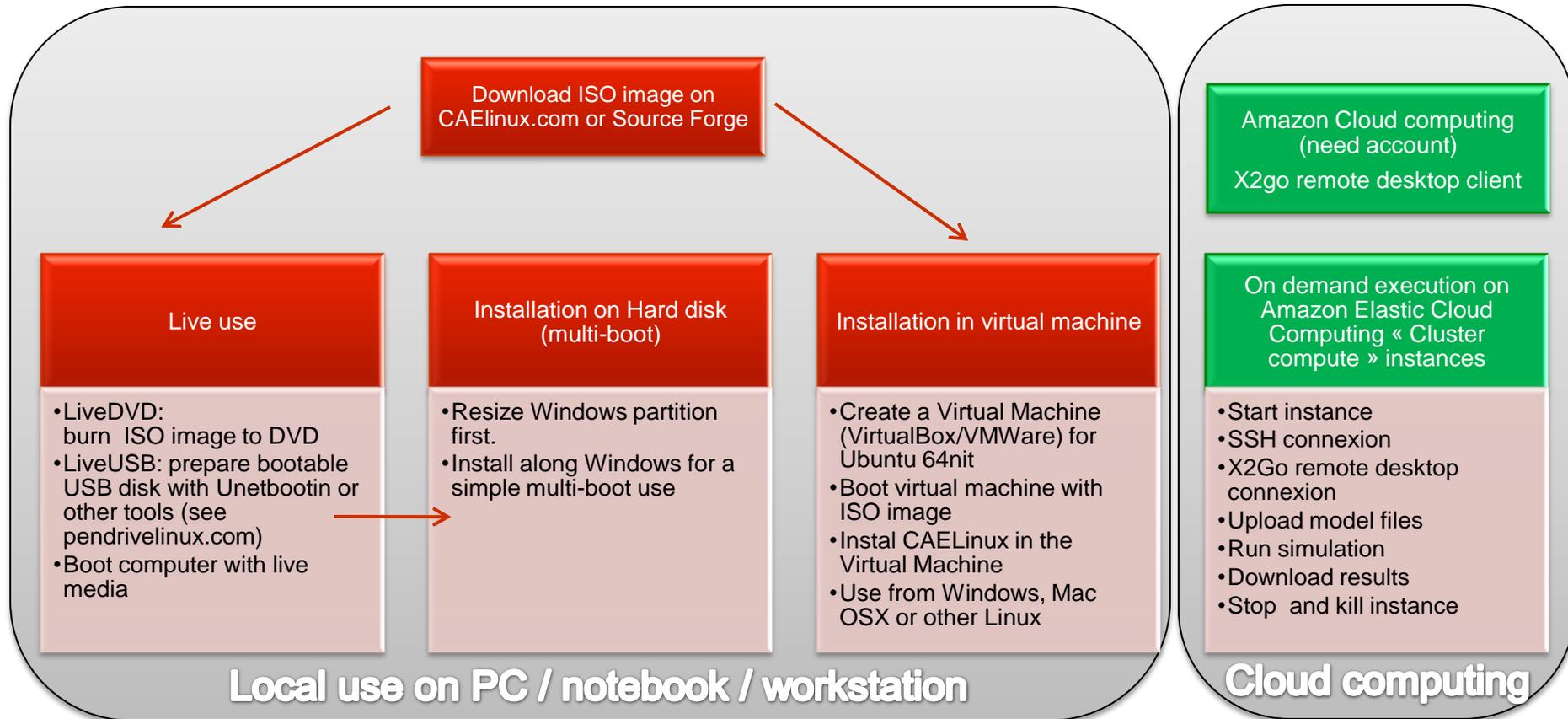
Elmer is a multiphysics FE solver with implicit coupling: segregated physics FE solvers linked in an iterative minimization loop. Elmer supports parallel computing through OpenMPI.

Exemple: Salome (unv) - ElmerGUI –Elmer

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

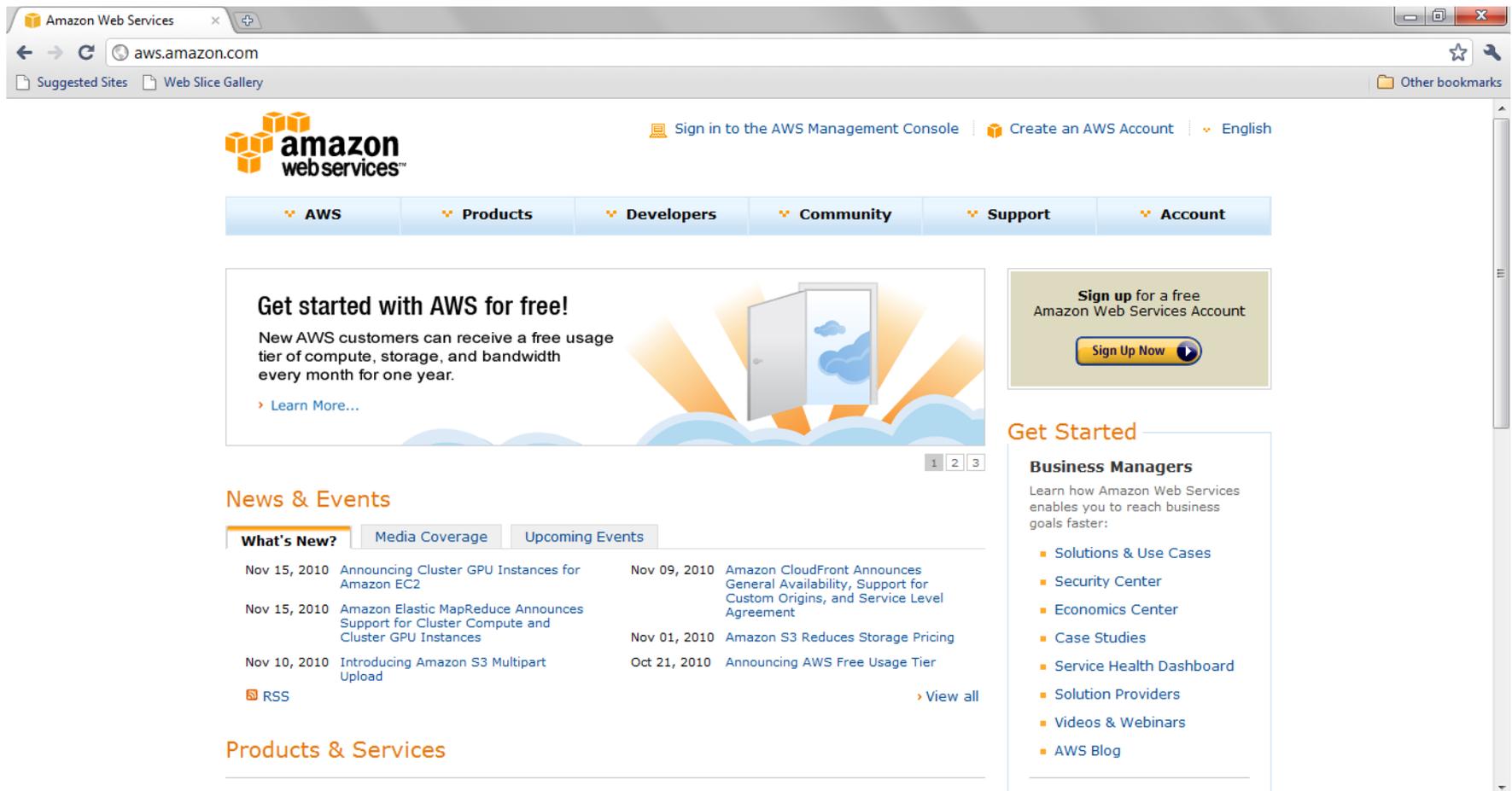


How to deploy / use CAELinux ?



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 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 shows the SALOME 5.1.3 CAD/CAE software interface. The Object Browser on the left lists the loaded model components, including Geometry (piston.stp_1), Mesh, Hypotheses, Algorithms, Mesh_1, Aster (linear-static), and Post-Pro (linear-static.rmed). The main 3D viewer displays a wireframe mesh of a piston, colored with a gradient from blue to green. The viewer shows the position and size of the selected object. The desktop environment is Ubuntu, with the system tray showing the date and time as Wednesday, November 17, 2010, at 03:04 AM. A yellow text box at the bottom of the screenshot reads: "Remote desktop with X2Go Client From Windows/Mac/Linux!!".