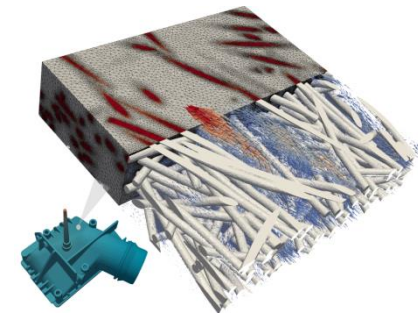
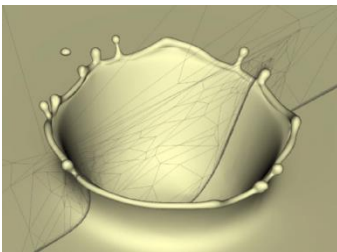
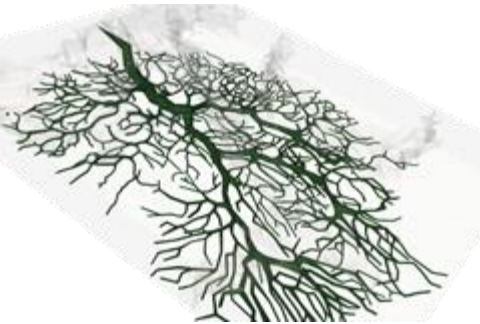
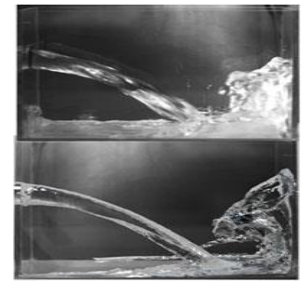




*Institut de Calcul Intensif ICI
Ecole Centrale de Nantes (ECN)*



Calcul intensif, croissance informatique

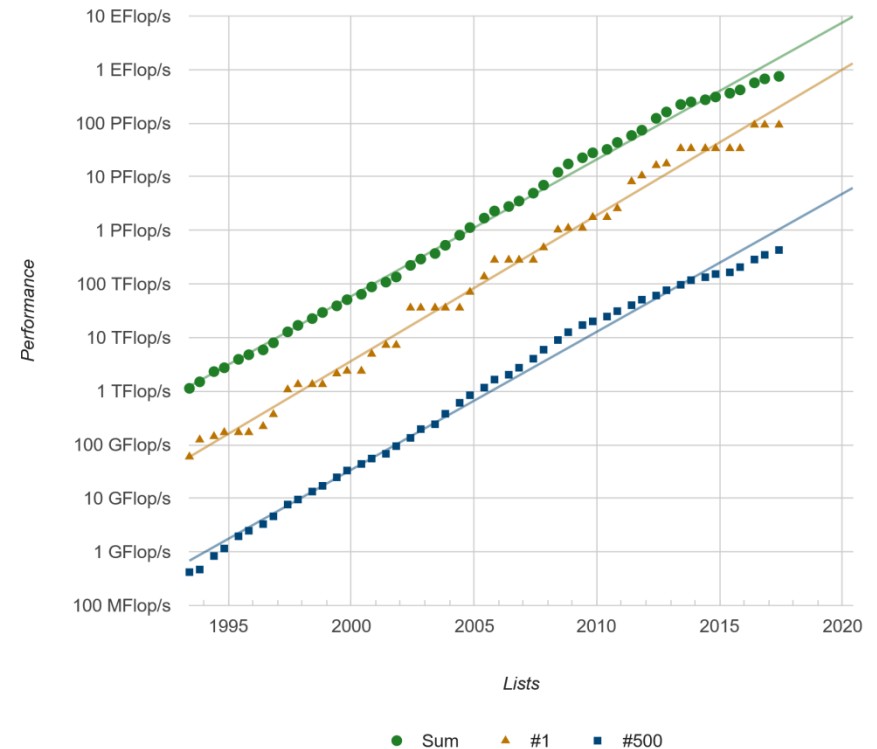
Calcul intensif:

- HPC calcul massivement parallèle
- La recherche en méthodes numériques avancées
- Enjeux du calcul
 - Recherche : théorie – simulation – expérience
 - Industrie : conception-simulation –essai
 - Société: IA

Sunway TaihuLight
93 Pflops
> 10 million cores



Projected Performance Development



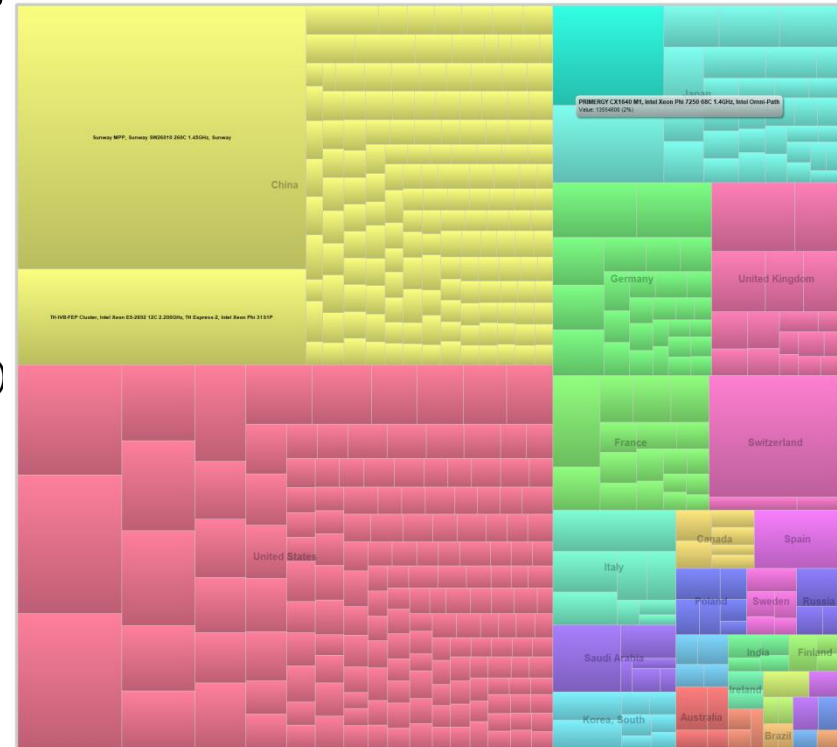
ExaFlop = 1 000 000 000 000 000 000 flops



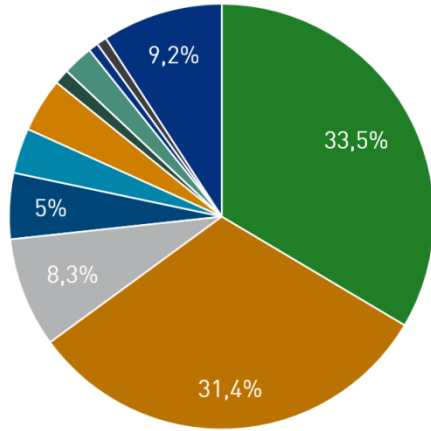
Calcul intensif, croissance informatique

Architectures massivement parallèles

- Des milliers, millions de cœurs
- Paradigme de programmation
 - 🌐 MPI, Thread, informatique et calcul
 - 🌐 Exascale: mixte?
- Mathématiques appliquées:
 - 🌐 EDP, analyse numérique, algèbre linéaire (HPC)
 - 🌐 Probabilités et statistique (Data sciences)
 - 🌐 Algorithmes
- Mécanique numérique
 - 🌐 CFD, CSD, turbulence, fluide structure
- Physique numérique
- Domaines émergents:
 - 🌐 sciences du vivant,
 - 🌐 imagerie-simulation
 - 🌐 données réelles, systèmes complexes
 - 🌐 Machine learning

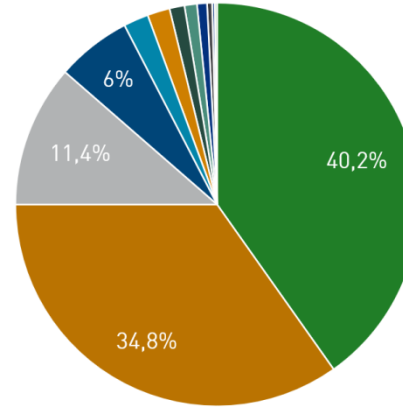


Countries Performance Share



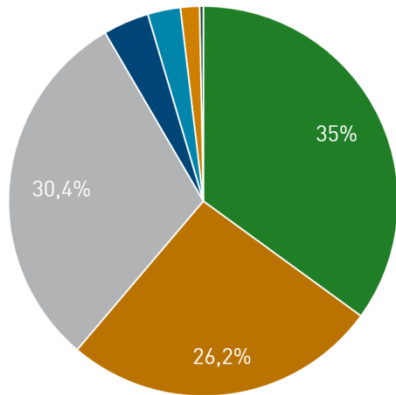
- United States
- China
- Japan
- Germany
- France
- United Kingdom
- Korea, South
- Italy
- Canada
- Poland
- Others

Geographical Region System Share



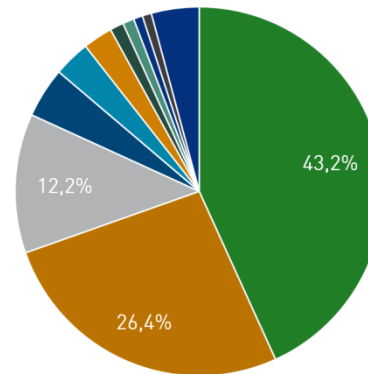
- Eastern Asia
 - North America
 - Western Europe
 - Northern Europe
 - Eastern Europe
 - Southern Europe
 - Western Asia
 - Australia and New Zealand
 - South-central Asia
- ▲ 1/2 ▼

Accelerator/CP Family Performance Share



- Nvidia Kepler
- Nvidia Pascal
- Intel Xeon Phi
- Nvidia Fermi
- Hybrid
- PEZY-SC
- ATI Radeon

Processor Generation System Share



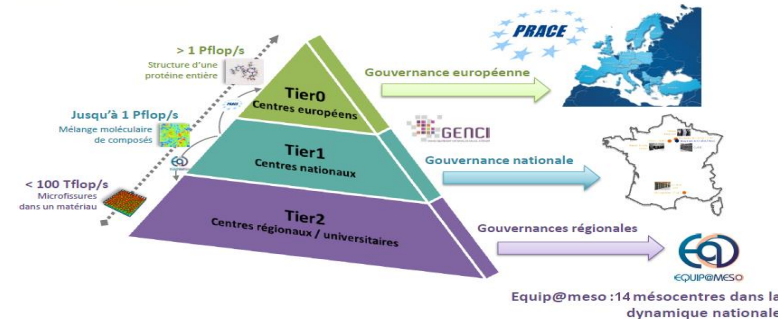
- Intel Xeon E5 (Haswell)
- Intel Xeon E5 (Broadwell)
- Intel Xeon E5 (IvyBridge)
- Intel Xeon E5 (SandyBridge)
- Power BQC
- Intel Xeon Phi
- Xeon 5600-series (Westm...)
- SPARC64 Xlfx
- Intel Xeon E7 (Haswell-Ex)
- Opteron 6200 Series "Inte..."
- Others

Création de l'ICI: laboratoire et centre de calcul

ICI-supercomputing: Positionnement dans le domaine du Calcul Intensif?

- modélisation de haut niveau
- partenariats industriels
- croissance des besoins numériques

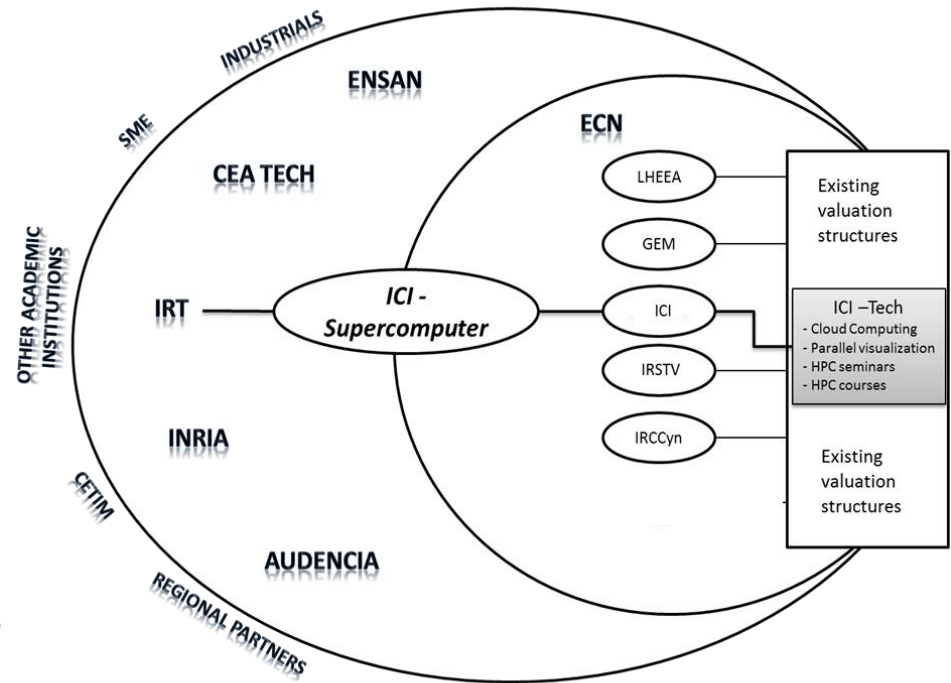
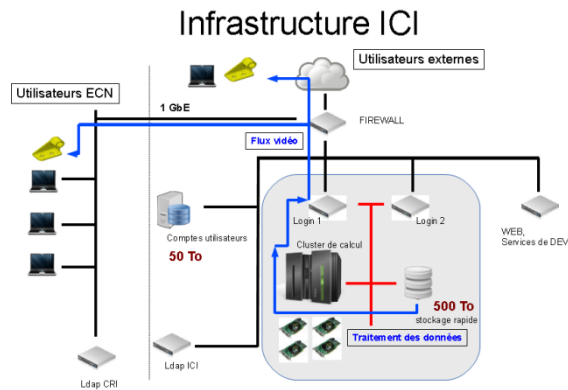
Calcul Intensif pour l'Industrie et la Société



ICI-lab

- Modélisation par le calcul et développement des méthodes numériques.
- Points d'excellence :
 - Méthodes du calcul intensif, maillage et adaptation, méthodes numériques
 - Calcul parallèle, ICItch (API)
- Nouveaux thèmes:
 - De l'image au maillage: calcul sur données réelles
 - [Reduction, machine learning: calcul offline](#)
- Développer des applications avec les autres centres de l'Ecole
- Des plateformes communes, logiciels et développements
- Collaborations nationales et internationales
- **Formation en calcul intensif et applications**

Réalisations: centre de calcul



Dates clés

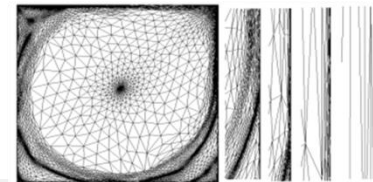
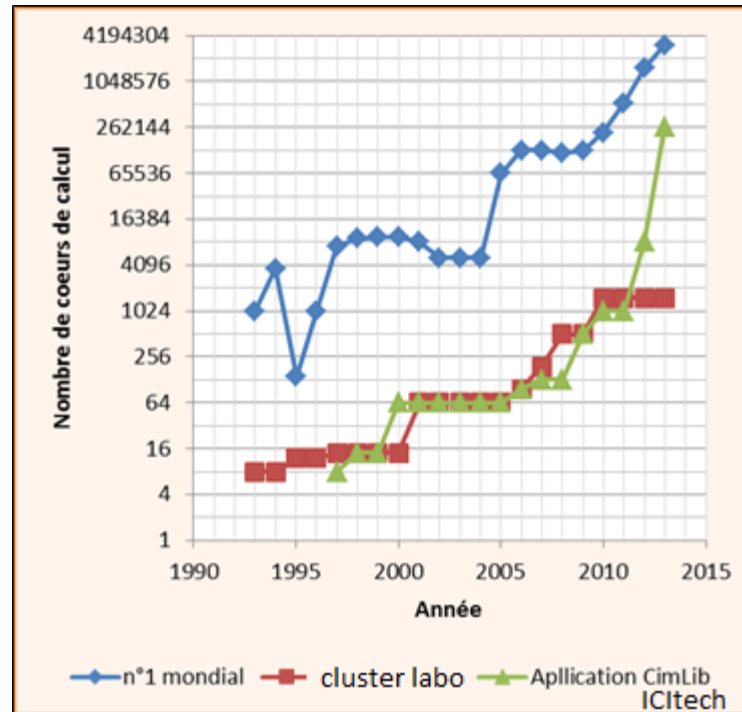
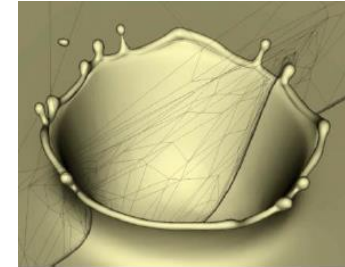
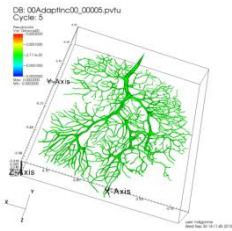
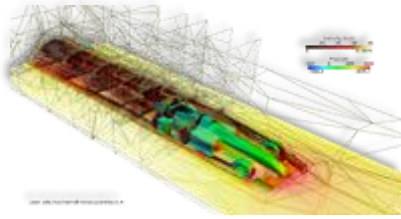
- Rédaction du CCTP, **4^{ème} trimestre 2014**
- Lancement AO du calculateur, **1^{er} trimestre 2015**
- Sélection du constructeur, **mai 2015**
- 1ers calculs à distance sur 864 cœurs (soit 36 nœuds), **juillet 2015**
- Début du chantier Méso+DC, **août 2015**
- Livraison de la salle, **début décembre 2015**
- Assemblage des 252 nœuds sur site, **mi-décembre 2015**
- Calculateur opérationnel à 6048 cœurs, **début janvier 2016**
- *Recette finale*, **fin février 2016**
- *Assemblage des 180 nœuds restants soit un total de 10368 cœurs*, **automne 2016**

Mesocentre de calcul

- **ICI-Supercomputing**, le Mesocentre de Calcul de Centrale de Nantes
 - Salle dédiée et sécurisée de 53m² avec 10 baies BULL/EfiRack
 - Utilisation
 - Académiques
 - Industrielles
- **LIGER**, le super-calculateur
 - 2015-2016: 252 nœuds + 14 nœuds hybrides ±6048 cœurs
 - Objectifs 2016
 - 432 nœuds (10,368 cœurs),
 - nœuds FAT (1 TB de mémoire),
 - stockage rapide GPFS de **+1,2 Po**
 - chiffrement des disques
 - Visualisation on-line avec le portail web Bull Extreme Factory (XCS)
 - Accès et réseau sécurisé (VPN, VLAN et SSH)



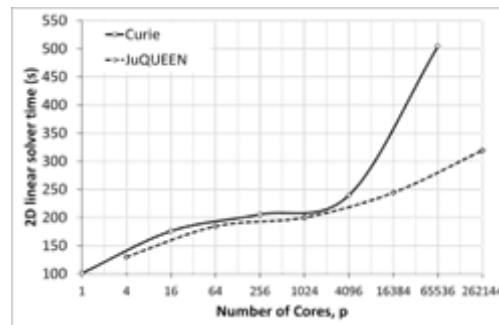
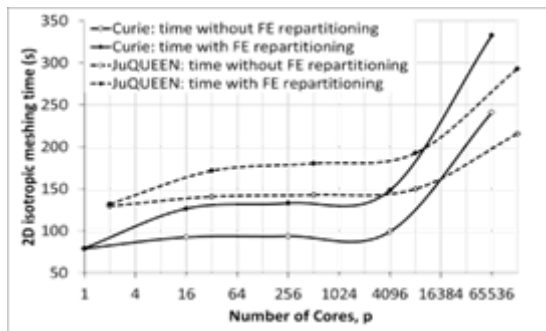
Convergence des performances matérielles et logicielles



Faits marquants

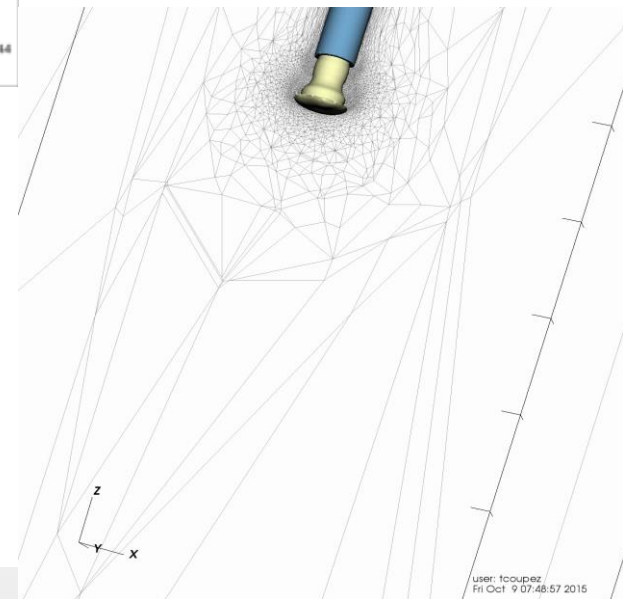
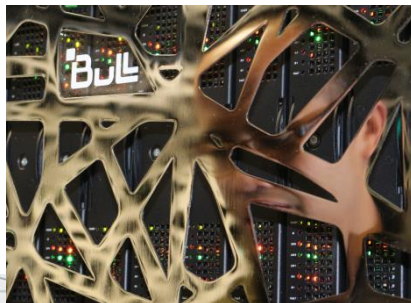
Connect Talent (4.2 Meuros)

Performances logicielles massivement parallèles



ICIttech et CFD multiphasique
des premières applications industrielles

LIGER



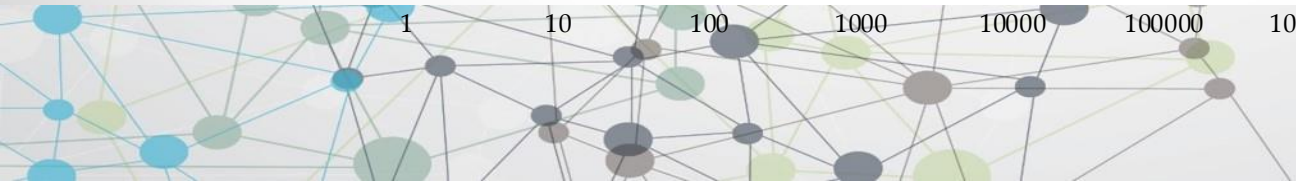
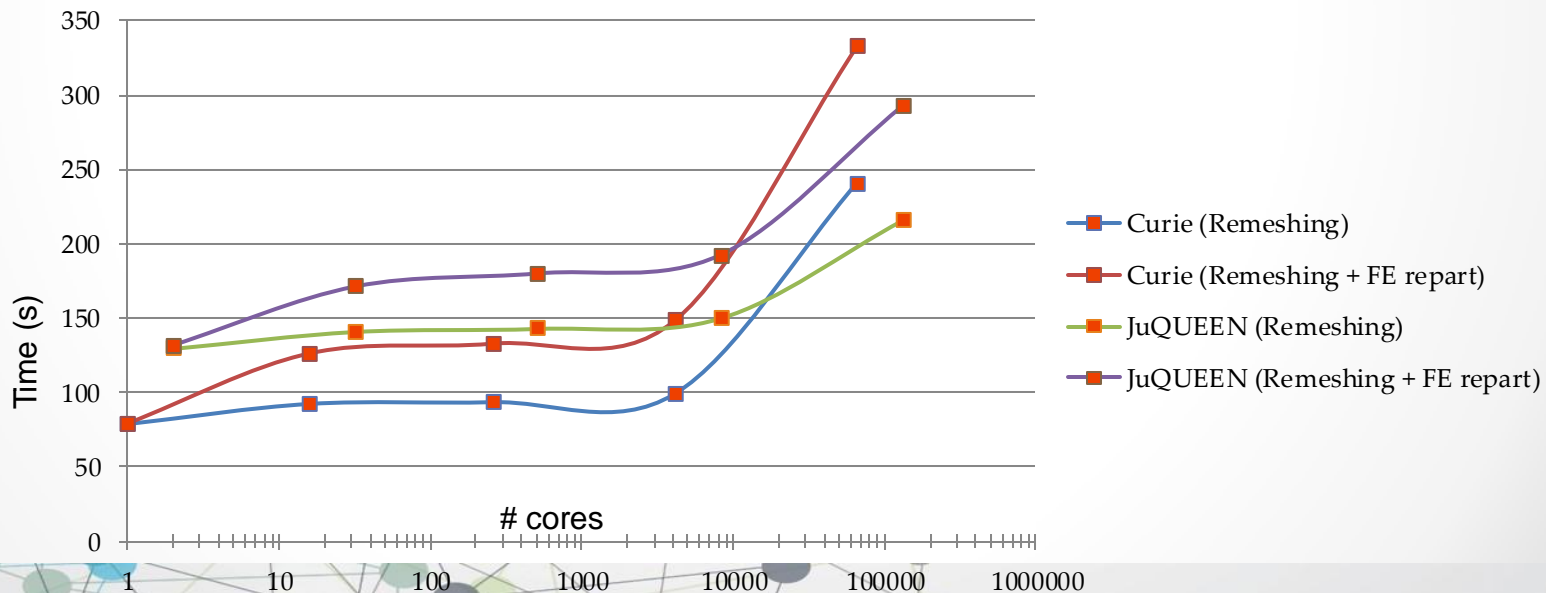
user: tcoupez
Fri Oct 9 07:48:57 2015

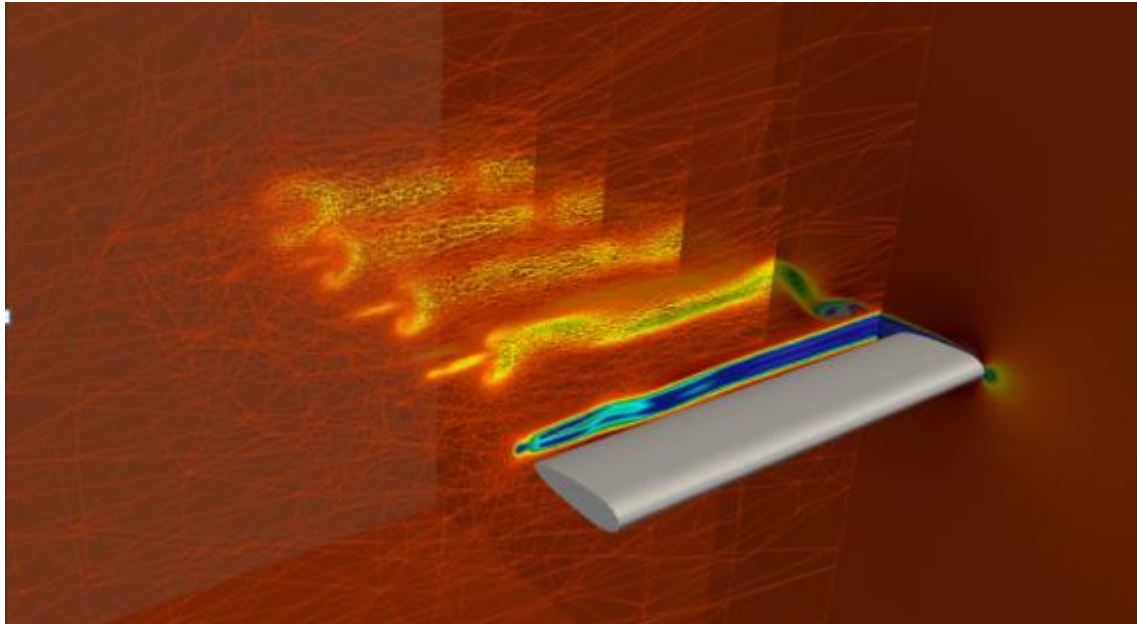
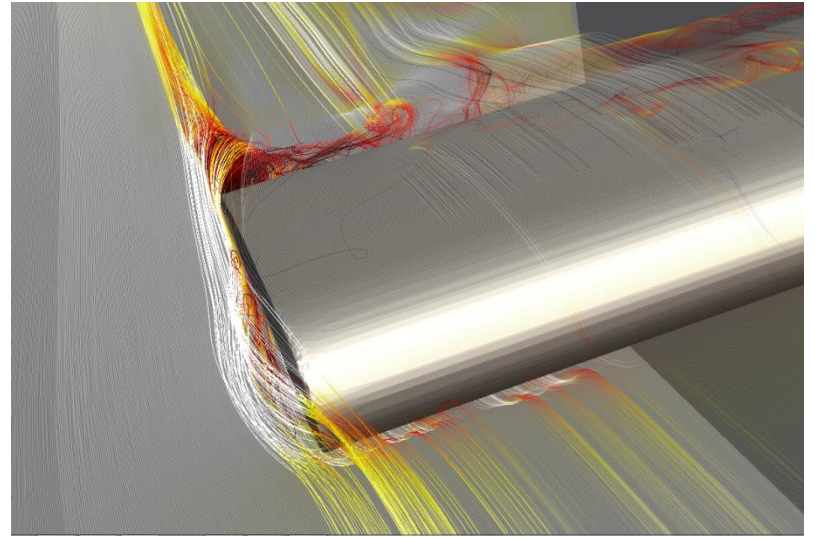
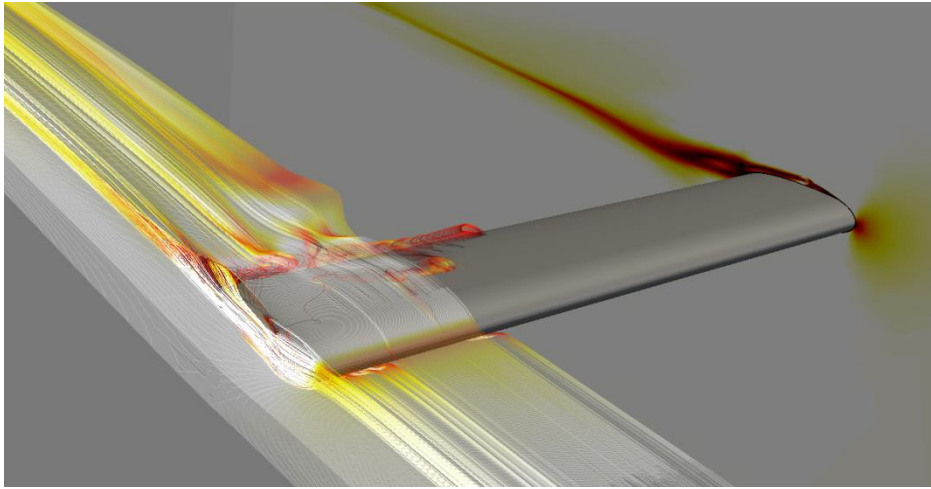
Massively parallel mesh generation



Weak speed up

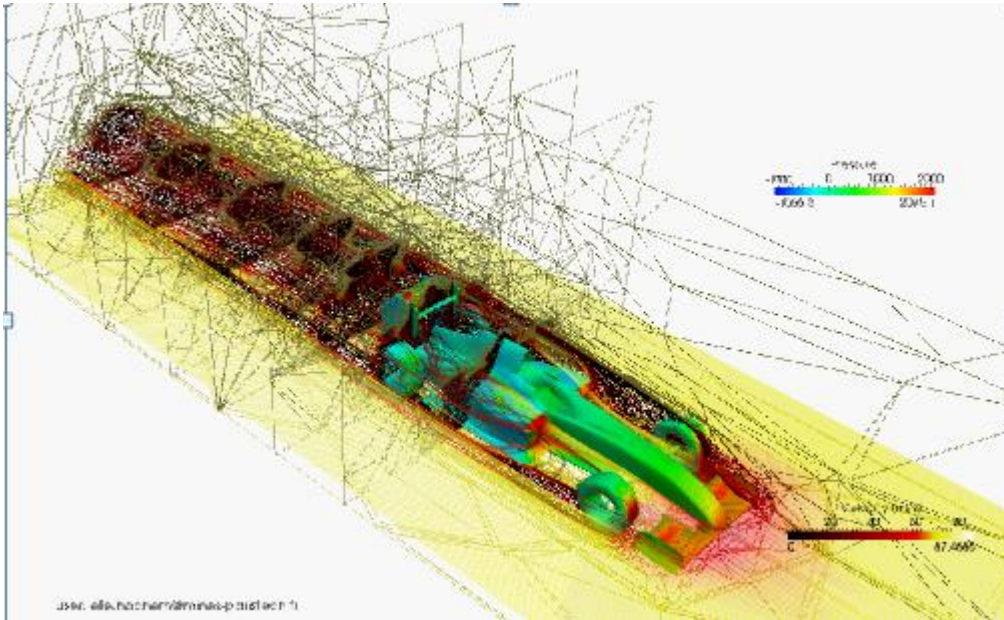
- Run from 1 to 131 072 cores, uniform mesh refinement by a factor 4, on **Curie** and **JuQUEEN**
- Constant load per core: 500 000 nodes on Curie and 250 000 on JuQUEEN
- Final mesh has **33.3 billions of nodes** (67 billions of elements)
- Good performances up to 8192 cores





Flow past a wing

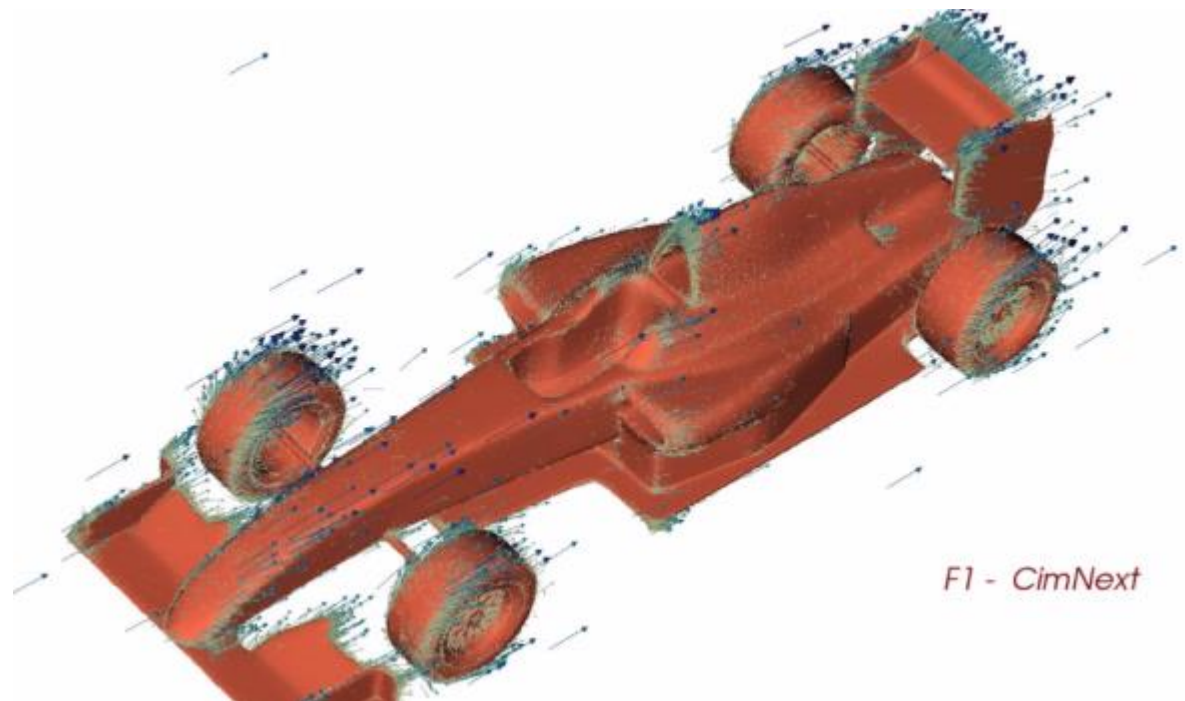
Co-worker: Geoffrey Tanguy



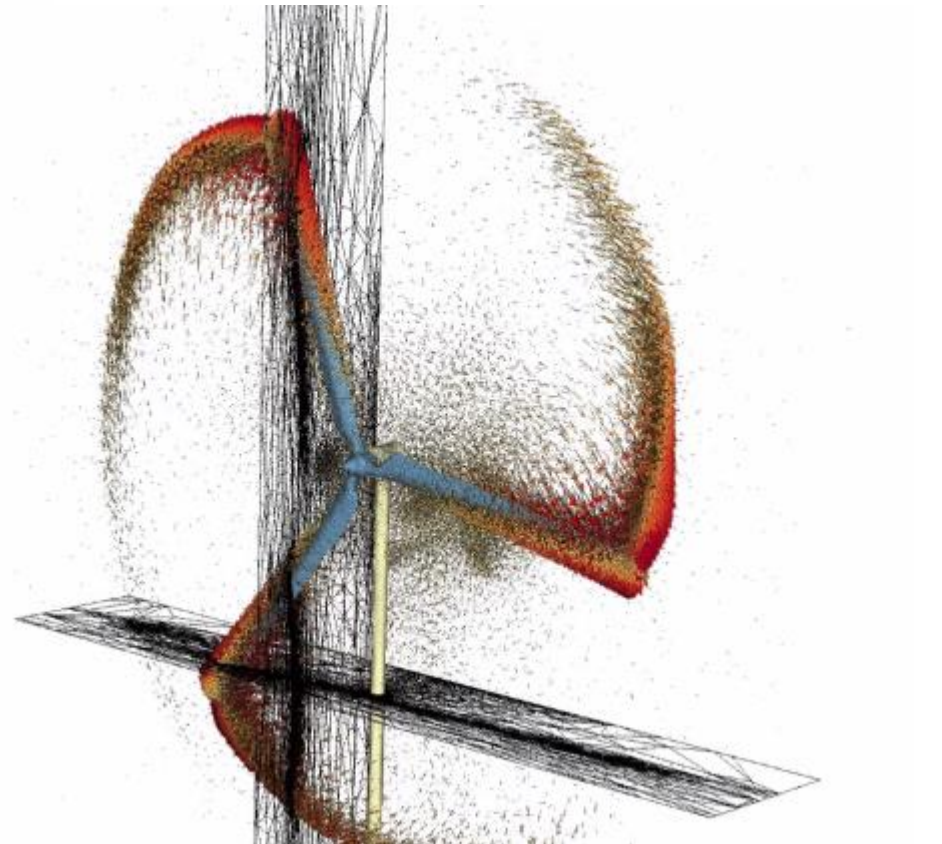
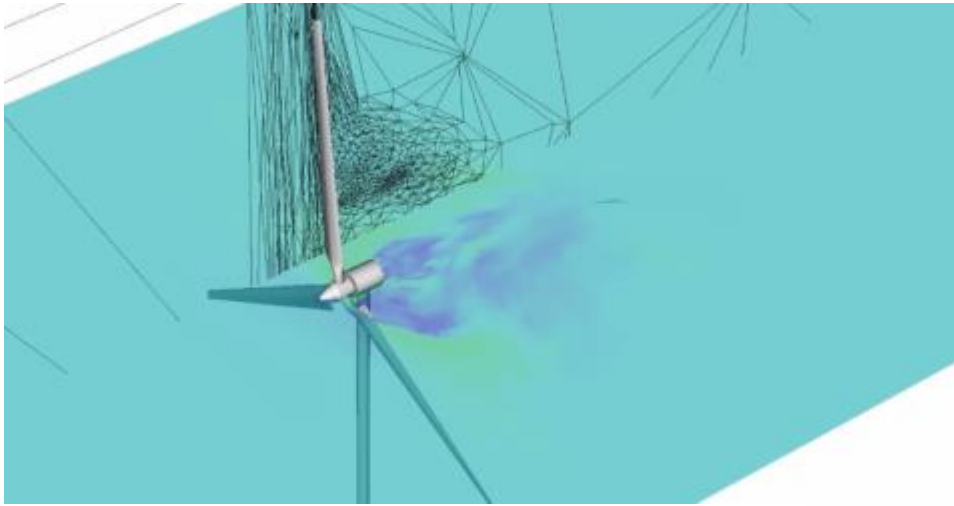
Aerodynamic at low Mach
 Stabilised Finite element:

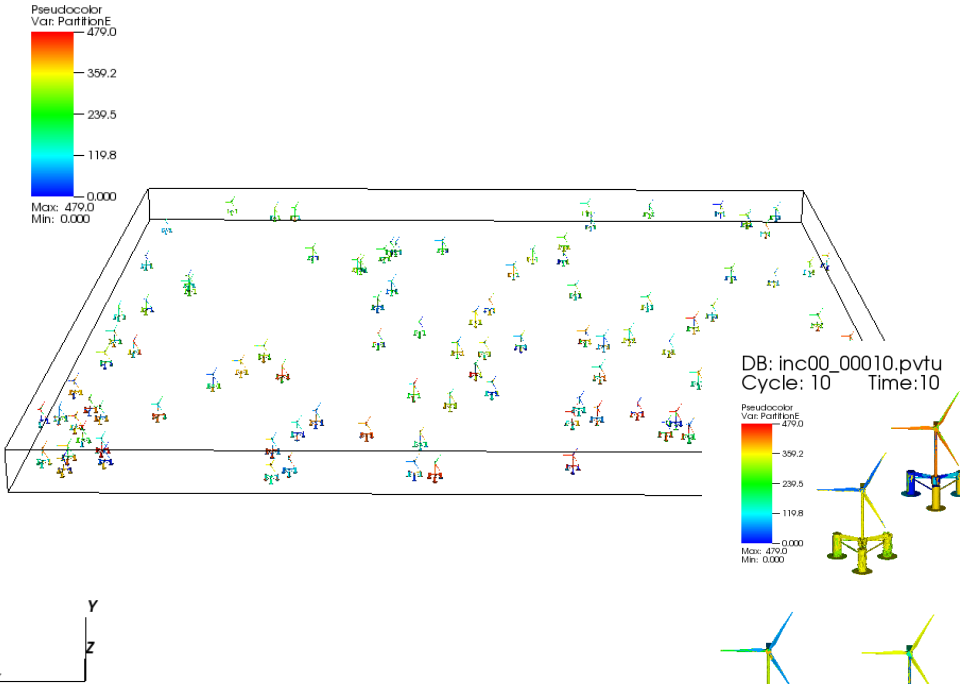
VMS = implicit LES

- Immersed volume
 - Multiphase to Fluid Structure
- **Anisotropic adaptive meshing:**
 - **Geometry recovery**
 - **Boundary layer**
 - **Monolithic FSI**



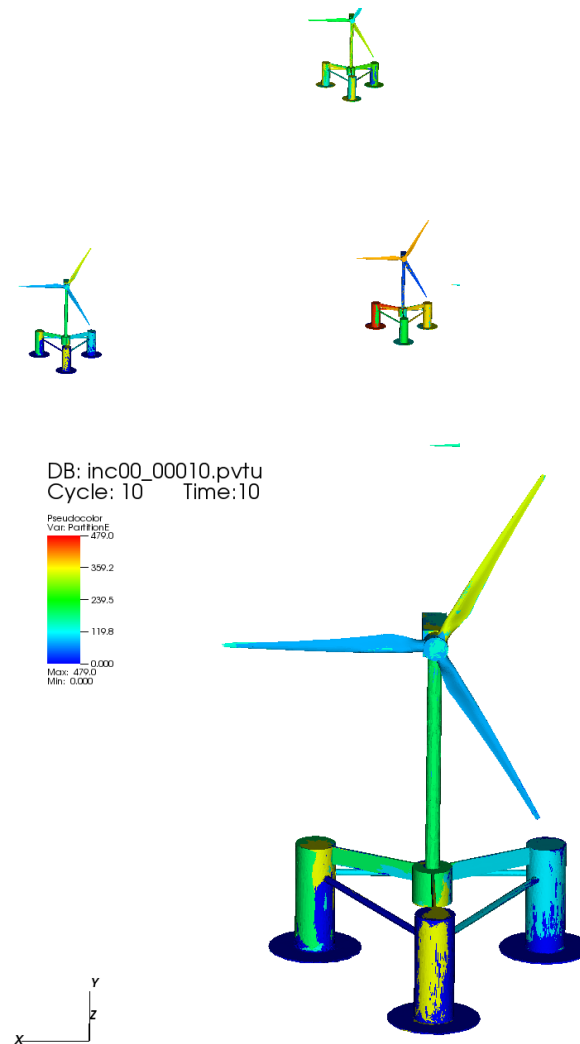
Energies marines: éolien offshore

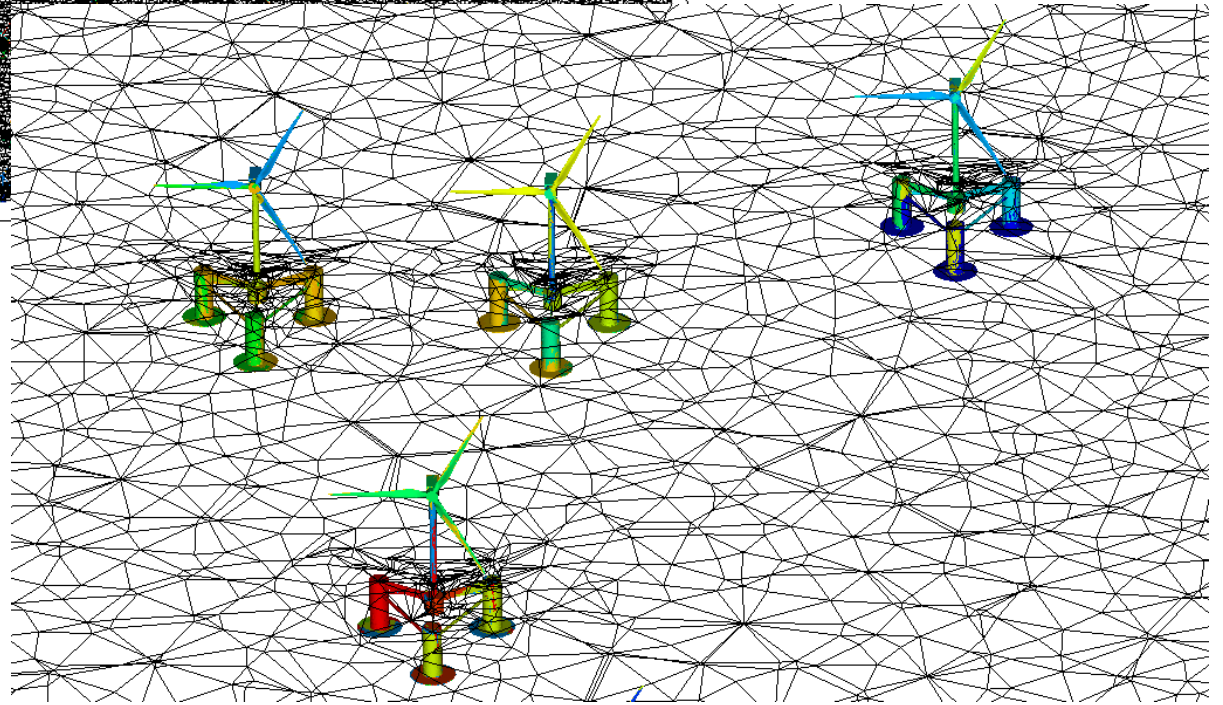
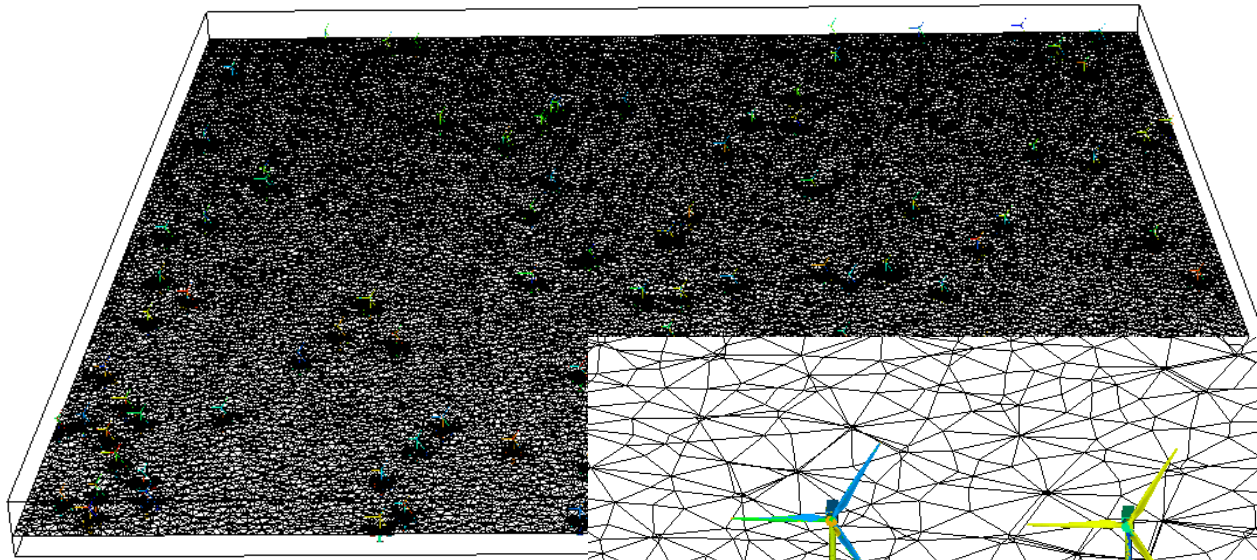




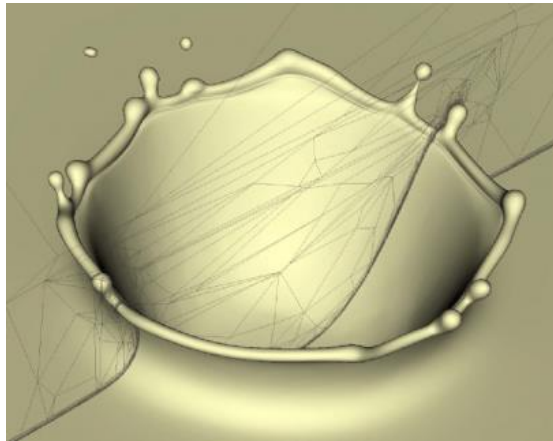
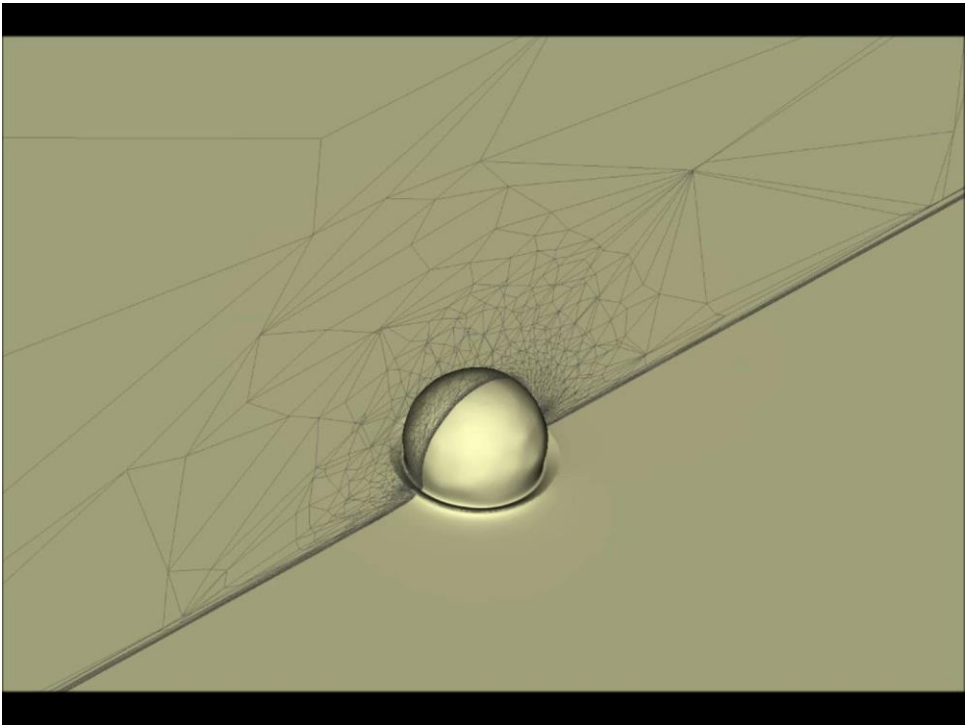
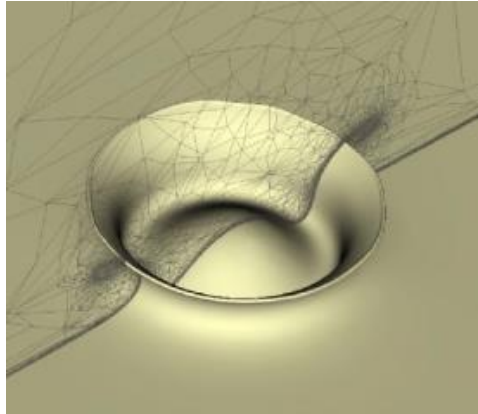
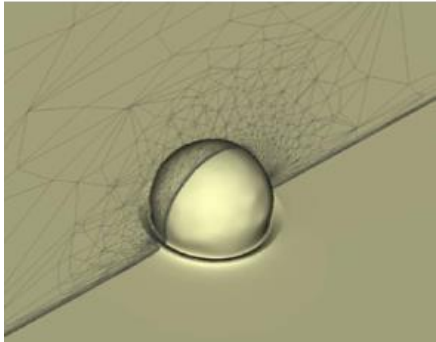
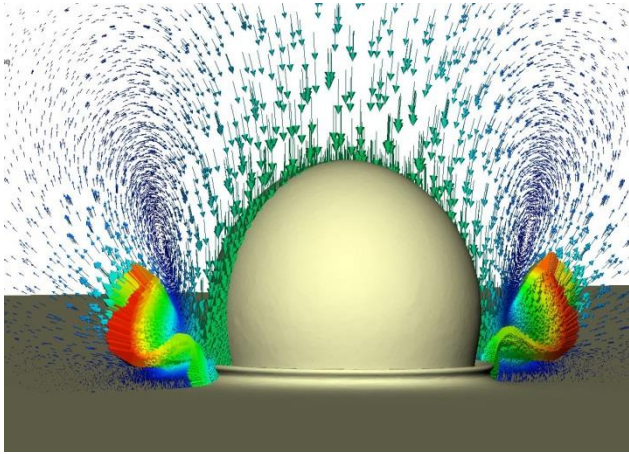
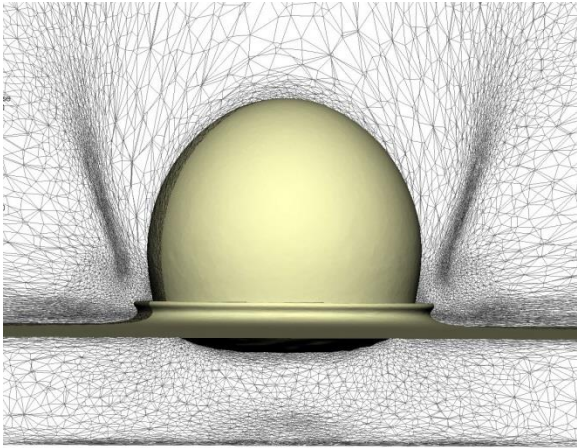
Projet EOS

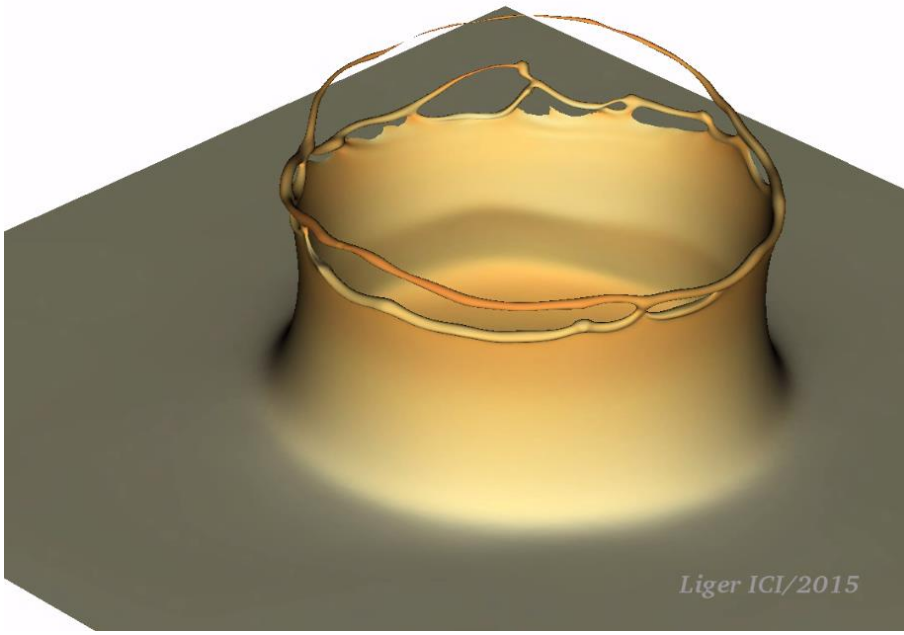
100 Floating wind turbines
 Placed randomly
 Dimension: 1*1.5*0.8
 50*2.5*50
 Thickness= 0.0002
 30M mesh nodes
 480 cores



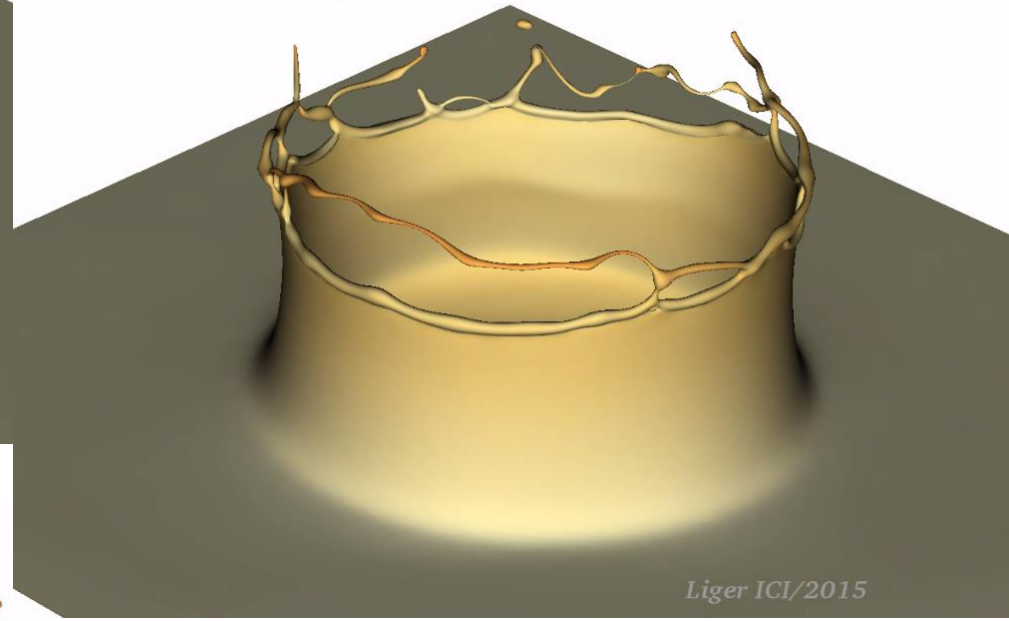


Droplet splashing with surface tension and crown phenomenon

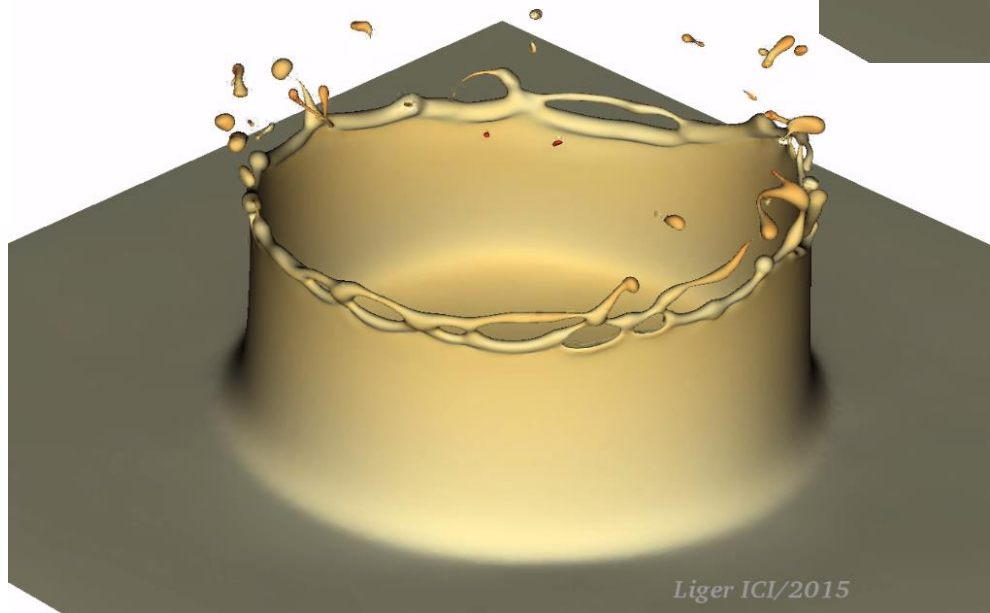




Liger ICI/2015

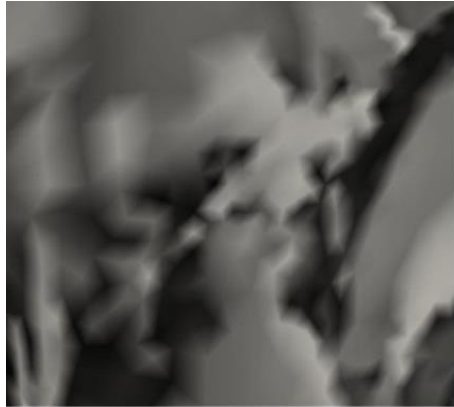


Liger ICI/2015



Liger ICI/2015

Image Meshing by controlling the Pixel interpolation error ("image compression")



(a) 500 nodes



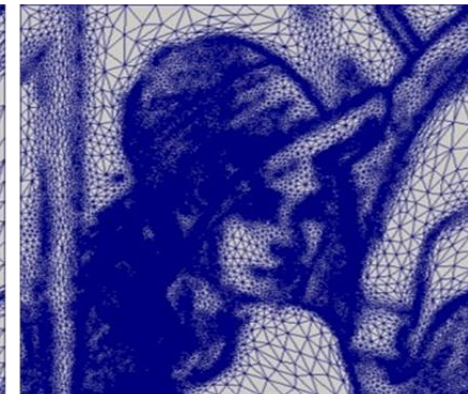
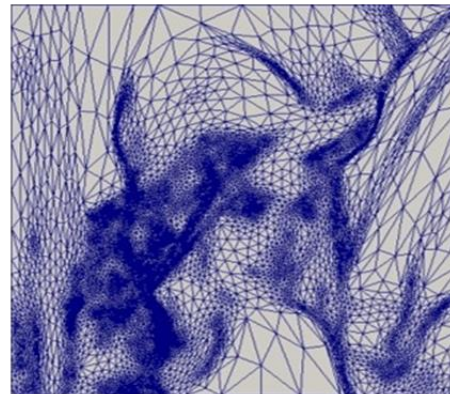
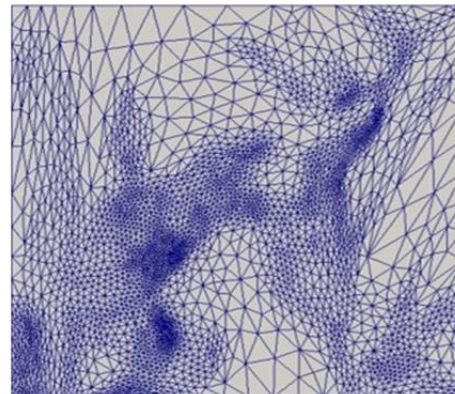
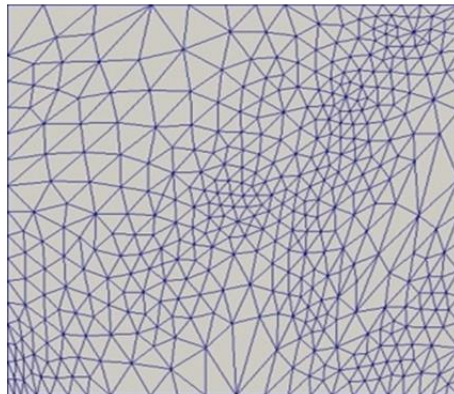
(b) 3214 nodes



(c) 12758 nodes



(d) 82427 nodes



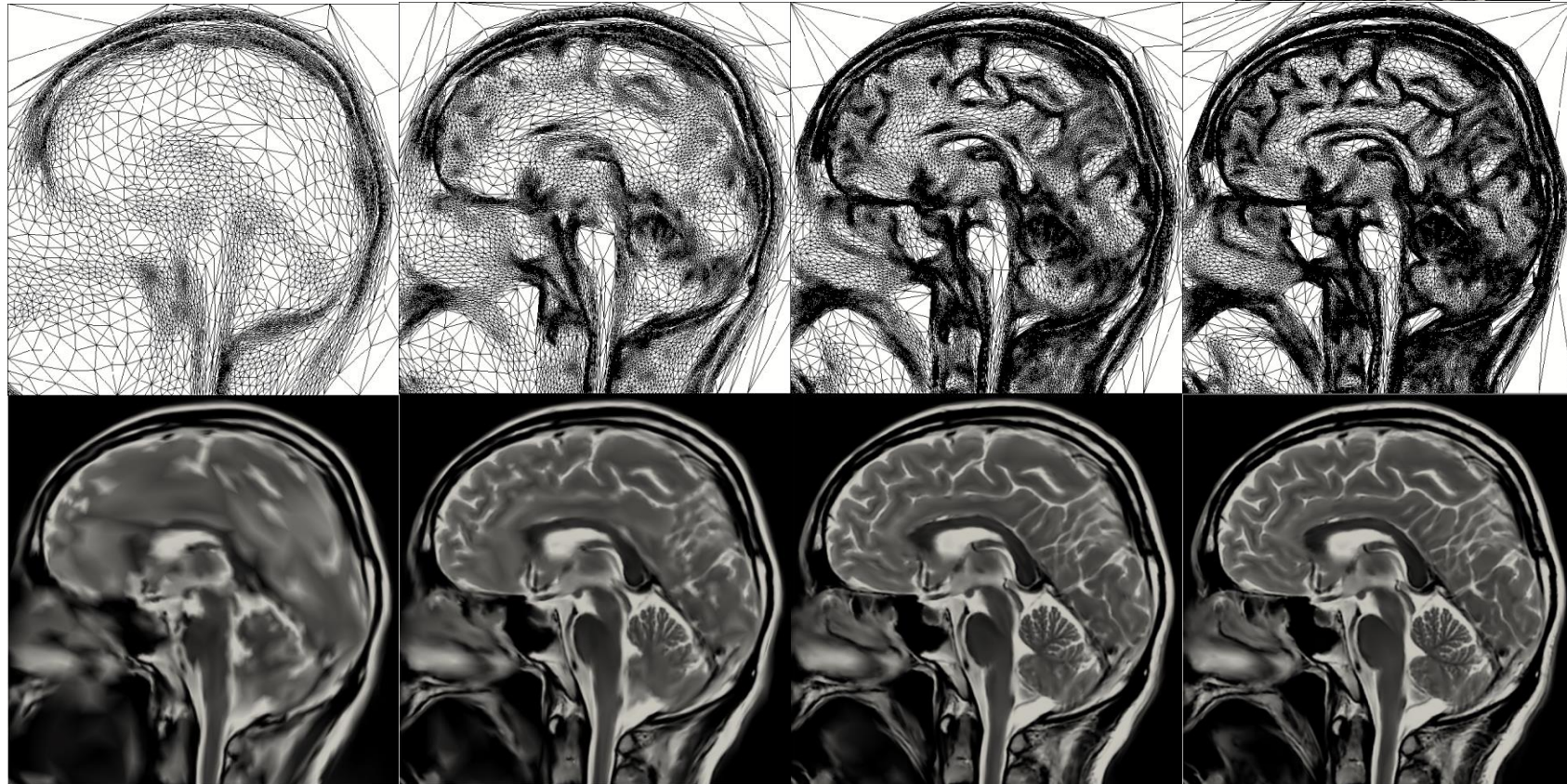
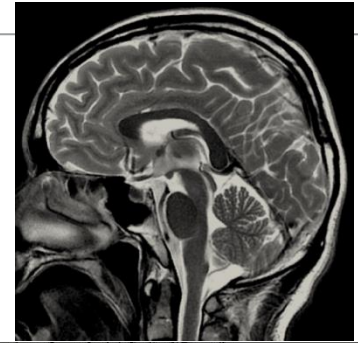
J.X. Zhao, T. Coupez, E. Décencière, D. Jeulin, D. Cardenas-Pena, L. Silva. Direct multiphase mesh generation from 3D images using anisotropic mesh adaptation and a redistancing equation', Computer Methods in Applied Mechanics and Engineering 2016

Direct image meshing

Image (700 × 700)

○ Image immersion with adaptive anisotropic meshing

Number of nodes control: (**superpixelisation**)
(15 iterations in one core)



3600 nodes, 50s

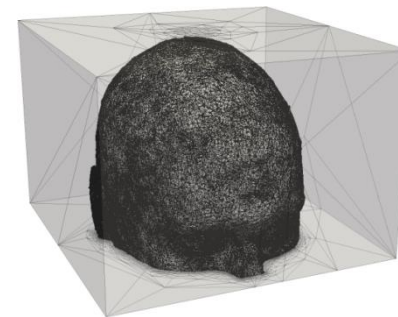
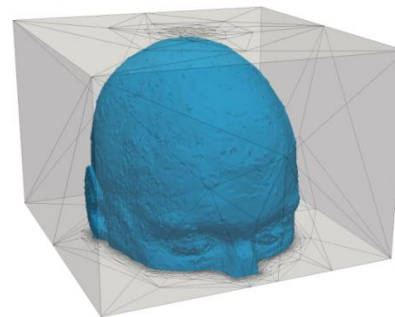
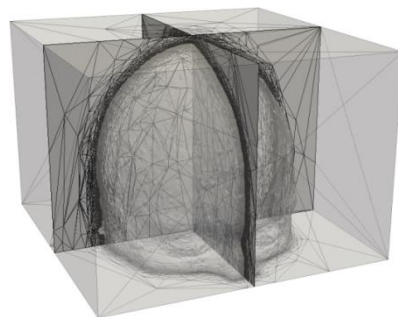
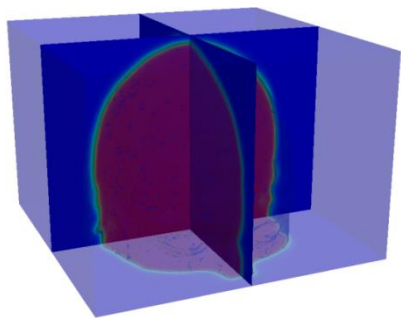
13000 nodes, 107s

32000 nodes, 202s

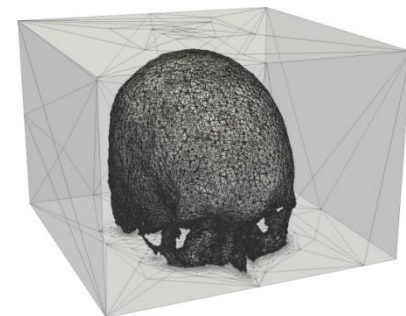
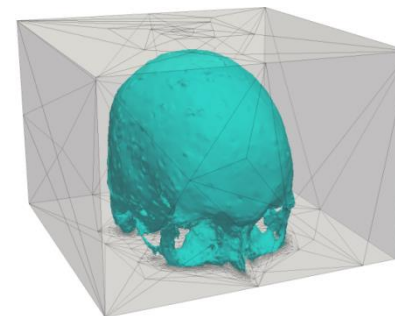
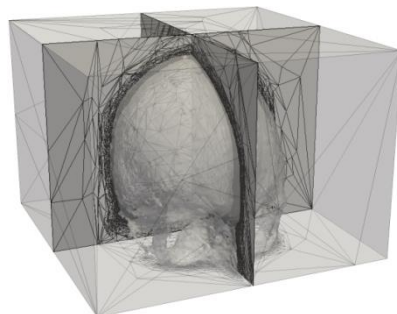
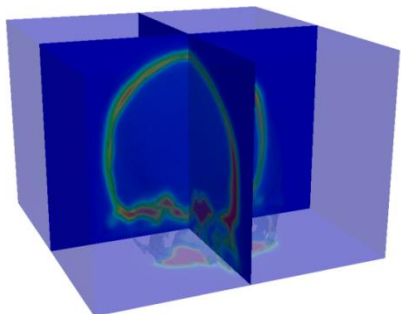
53000 nodes, 331s

[Silva et al, 2014] [Zhao et al, 2016]

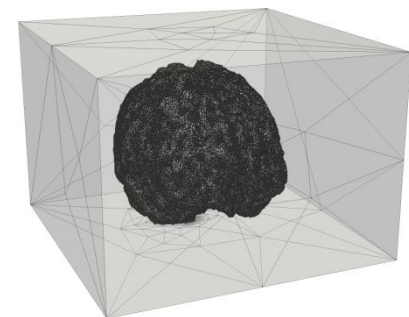
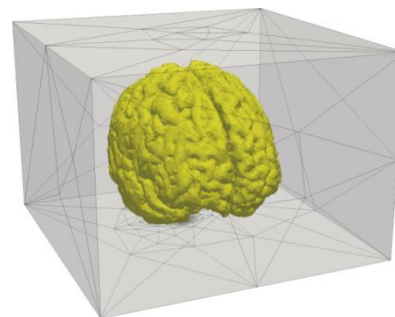
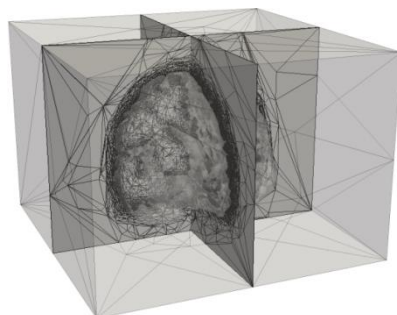
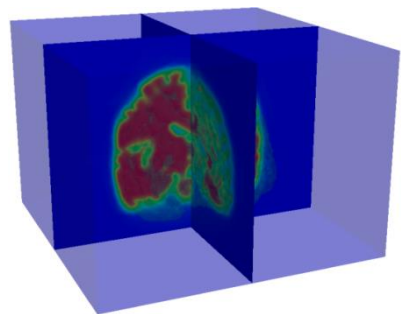
Segmentations (3d multiphase): Hamilton Jacobi solver and mesh adaptation based on interpolation error



$N = 200000$, 148.4 mins 6 cores



$N = 300000$, 183.8 mins 6 cores

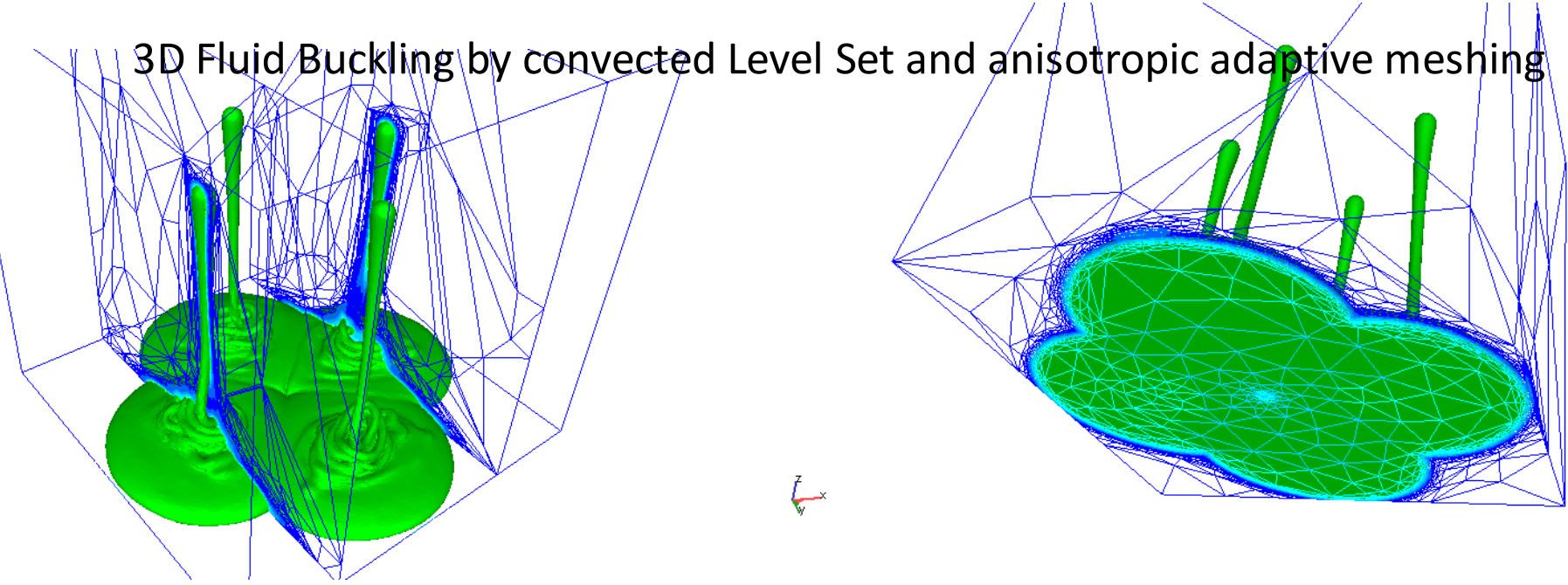


$N = 400000$, 233.9 mins

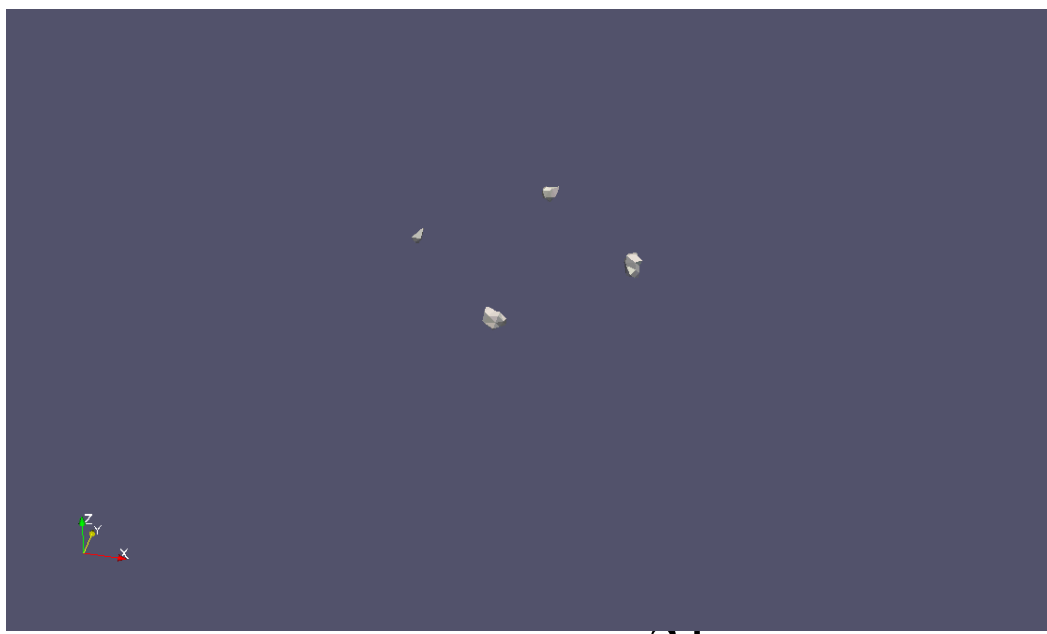
Iso-zero surface of u_ϵ^τ

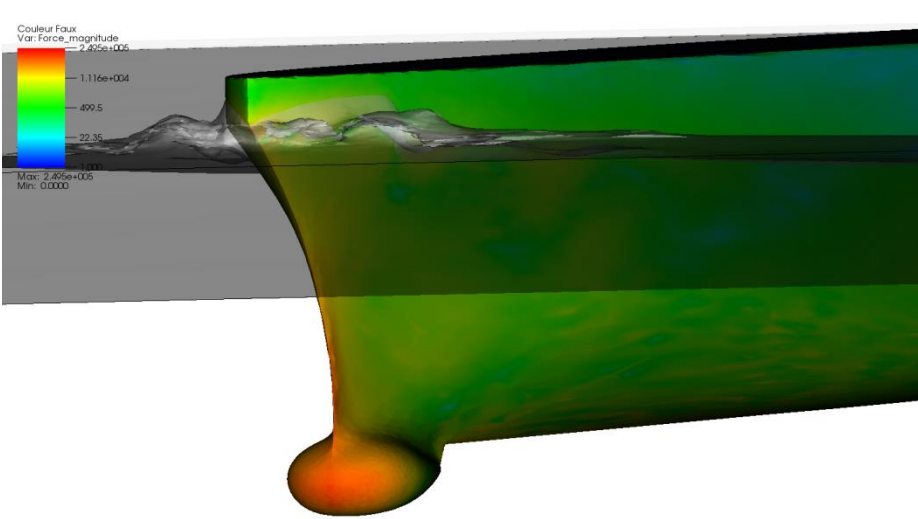
Surface mesh

3D Fluid Buckling by convected Level Set and anisotropic adaptive meshing



*Ariane 6: booster reservoir filling
(Airbus Safran Launcher)*



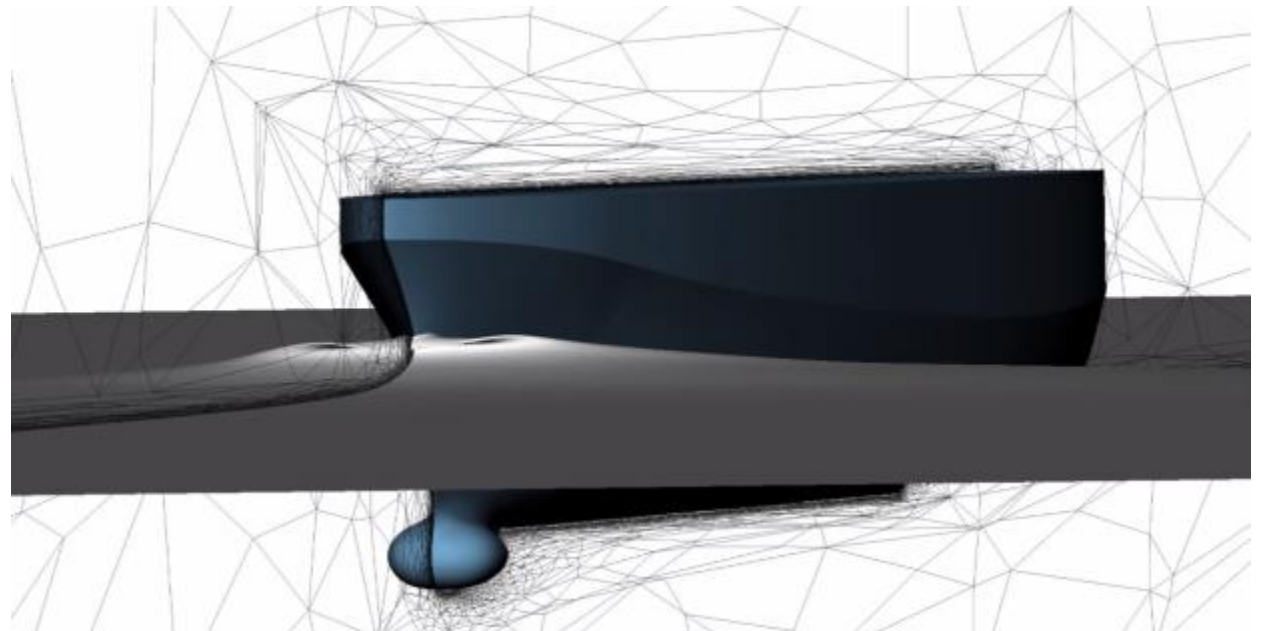


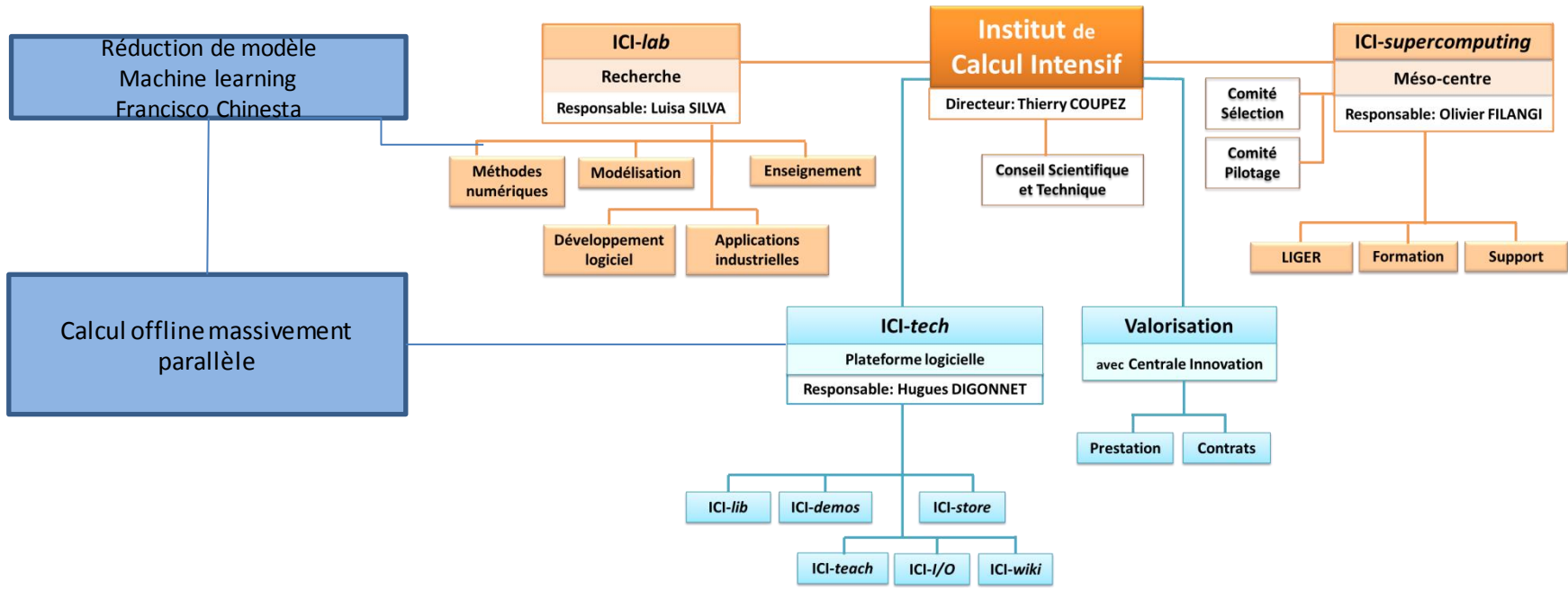
user: fcoupez



10/22/15

Flow past a ship: drag, waves, ...
 Collaboration: NextFlow





Réduction de modèle
Machine learning
Francisco Chinesta

Calcul offline massivement
parallèle

ICI-lab
Recherche
Responsable: Luisa SILVA

Méthodes
numériques

Modélisation

Enseignement

Développement
logiciel

Applications
industrielles

**Institut de
Calcul Intensif**
Directeur: Thierry COUPEZ

Conseil Scientifique
et Technique

ICI-supercomputing
Méso-centre
Responsable: Olivier FILANGI

Comité
Sélection

Comité
Pilotage

LIGER

Formation

Support

ICI-tech
Plateforme logicielle
Responsable: Hugues DIGONNET

ICI-lib

ICI-demos

ICI-store

ICI-teach

ICI-I/O

ICI-wiki

Valorisation
avec Centrale Innovation
Prestation
Contrats

• Démocratisation du Calcul Intensif

- énergie : simulation d'éolienne et champ d'éoliennes offshore (LHEEA, ICI) ;
- société : simulation des environnements urbains et côtiers, climat et micro-climat (CRENEAU, LHEEA, ICI) ;
- matériaux et procédés : matériaux virtuels, mise en forme, endommagement et rupture, usine virtuelle... (GeM, ICI) ;
- ingénierie : aérodynamique de véhicules terrestres et aériens : soufflerie numérique, ...
- imagerie : simulation à partir des données réelles (tomographie, laser, satellite (Gem,Lhea, ICI,...) ;
- ingénierie numérique : « cloud computing », « big data », parallélisme massif (ICI).



Perspectives

- 🌐 **Éléments finis d'ordre élevé:**
 - Éléments finis d'ordre élevé, stabilisation, et maillage adaptatif anisotrope P2 courbe
 - Applications industrielles : > 1000-10000 cœurs
 - Plateforme mixte: multicœurs distribués (MPI-multithreading), exascale
 - Multigrille, Maillage-partionnement
- 🌐 **Multiphasique multiphysique**
 - fluide structure, microfluidique, magnétohydrodynamique (MHD)
 - Calcul à partir d'images et nuage de points
 - 🌐 Matériaux, imagerie médicale
 - 🌐 Environnements urbains et côtiers (lidar, images satellites)
- 🌐 **Relations industrielles**
 - Chaire ATOS-BULL sur le calcul intensif
 - Partenariat Arcelor-Mittal CFD multiphasique
- 🌐 **ICI-supercomputing**
 - Ouverture et inauguration du mésocentre
 - LIGER extension à 10000 cœurs
- 🌐 **Traitements massifs de données et production de modèles**
 - Réduction de modèles et machine learning,...

References

- T. Coupez, L. Silva, E. Hachem. 2015. **'Implicit boundary and adaptive anisotropic meshing'**, New Challenges in Grid Generation and Adaptivity for Scientific Computing, 1-18, Springer International Publishing.
- H. Digonnet, L. Silva, T. Coupez. 2015. **'Using full Tier0 supercomputers for FEM computations with adaptive meshing'** Proceedings of the Fourth International Conference on Parallel, Distributed, Grid and Cloud Computing for Engineering, Civil-Comp Press, Paper 13.
- T. Coupez. 2011. **'Metric construction by length distribution tensor and edge based error for anisotropic adaptive meshing'**, Journal of Computational Physics, 230: 2391-405.
- L. Ville, L. Silva, T. Coupez. 2011. **'Convected level set method for the numerical simulation of fluid buckling'**, International Journal for numerical methods in fluids, 66: 324-44.
- T. Coupez, E. Hachem, 2013. **'Solution of high-Reynolds incompressible flow with stabilized finite element and adaptive anisotropic meshing'**, Computer Methods in Applied Mechanics and Engineering 267, 65-85
- H. Digonnet, T. Coupez, P. Laure, L. Silva, **'Massively parallel anisotropic mesh adaptation'**, International Journal of High Performance Computing Applications (soumis).
- J.X. Zhao, T. Coupez, E. Décencière, D. Jeulin, D. Cardenas-Pena, L. Silva. **'Direct multiphase mesh generation from 3D images using anisotropic mesh adaptation and a redistancing equation'**, Computer Methods in Applied Mechanics and Engineering 309, 288-306, 2016.

