# CARRIOCAS
# Collaborative High Performance Scientific Visualization

**22th ORAP Forum, Strasbourg**

Christophe MOUTON, EDF R&D, SINETICS
Jean-Philippe NOMINE CEA/DIF/DSSI
With contributions of : ECP, OXALYA



## AGENDA

- Introduction
- Part 1 : Goals of the « Collaborative High Performance Scientific Visualization » demonstrator of the CARRIOCAS project
- Part 2 : The first results of the CARRIOCAS teams
- Part 3 : Future work

# Introduction

## CARRIOCAS ?



## CARRIOCAS

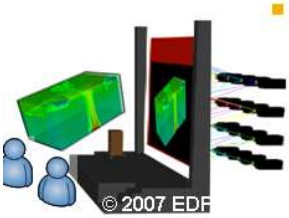
- **« Distributed Computation Over Ultra High Speed Optical Internet Network »**
- **In french : « CAlcul Réparti sur Réseau Internet Optique à CApacité Surmultipliée »**

- A 3-year project in the frame of the French SYSTEM@TIC Competivity Cluster: Oct. 2006 – Sept. 2009

# CARRIOCAS : Ambition

- **40 Gbits to model and simulate en real time**

  - **Adaptation of optic techniques to reach this ultra high bit rate**
  - **Integration and validation on an experimental network at the top level bit rate of 40Gb/s**
  - **R&D for distributed applications:**
    - **Distributed storage of massive data on remote servers**
    - **Remote Collaborative High Performance Scientific Visualization**






# Partnership

Project leader
WP (40Gb/s transmission) and
WP 2 (protocols and network architecture)

Academics

91 92 78 75

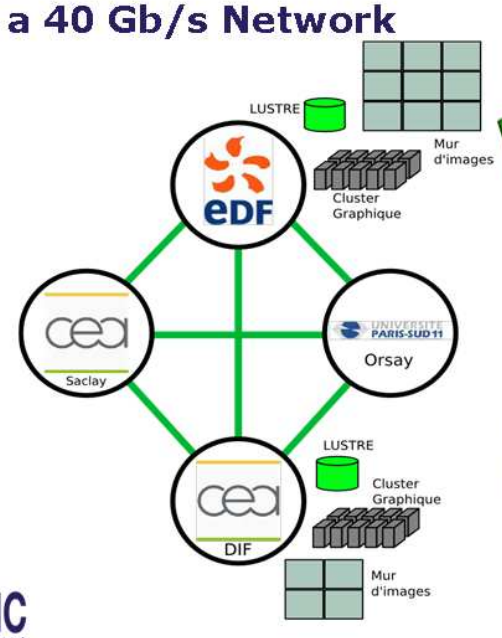
WP4 leader
(Distributed applications)

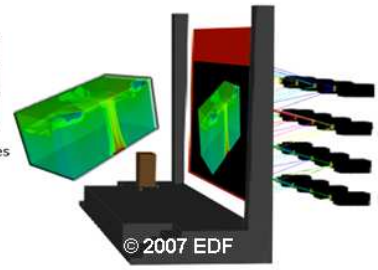
176 people.year
Oct 2006-Sept 2009

WP 3 leader
(experimental network)

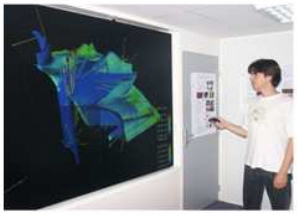
With the financial support of:

- **CARRIOCAS in 3 lines**
  - A Distributed Massive FileSystem (LUSTRE)
  - Remote High Performance Scientific Visualisation
  - **Over a 40 Gb/s Network**




Credits : Courtesy of CEA





Distributed Computation Over Ultra High Speed Optical Internet Network

# Part 1 : Goals of the « Collaborative High Performance Scientific Visualization » demonstrator of the CARRIOCAS project

Scientific and Industrial context
Focus on the daily use of HPC
inside a Power Utility : EDF

# Scientific and industrial Context 1/2

- High Performance Computing :
  - Examples of recent HPC ressources by the CARRIOCAS Partners
    - CCRT : Bull, Platine :47 Tflops, 26th top500
    - EDF R&D : IBM Bluegene/L : 22,9 Tflops, 53d top500

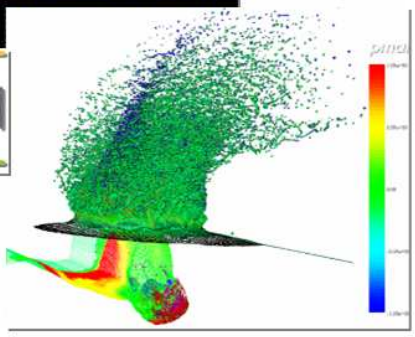

Credits : Courtesy of CCRT/CEA


Credits : EDF, courtesy of IBM

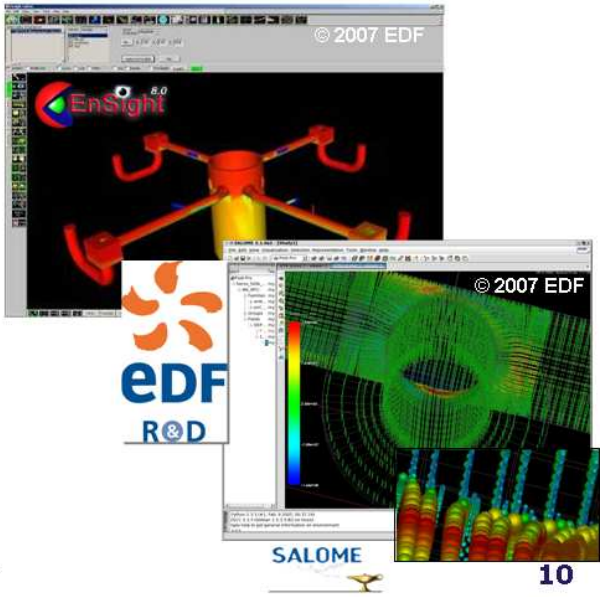


# Scientific and industrial Context 2/2

- HPC : a compulsory tool for deep challenges :
  - Defense, Energy and Research : **CEA**
  - Energy of today and tomorrow : **EDF**

Credits : Courtesy of CEA

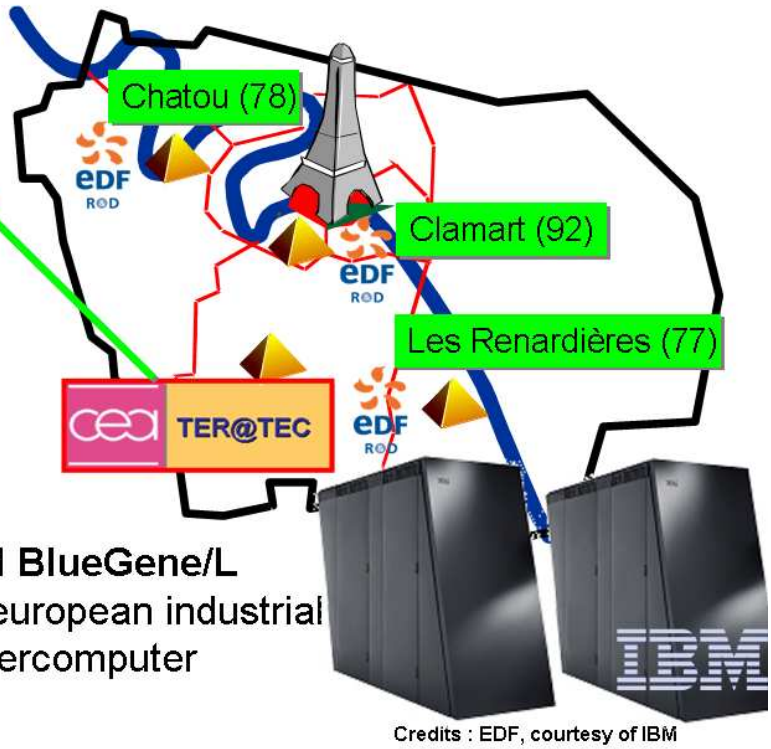


# REX of HPC use in a Power Utility : EDF

## EDF R&D : 600 researchers using HPC ressources


**09/07 CCRT-B 43 TFlops**
**EDF Use = ¼ CPU Time**

EDF HPC Power Use
2003 : 0,4 TeraFlops
2004 : 1,5 TeraFlops
2005 : 2,5 TeraFlops
2006 : 17,5 TeraFlops
2007 : 39,5 TeraFlops

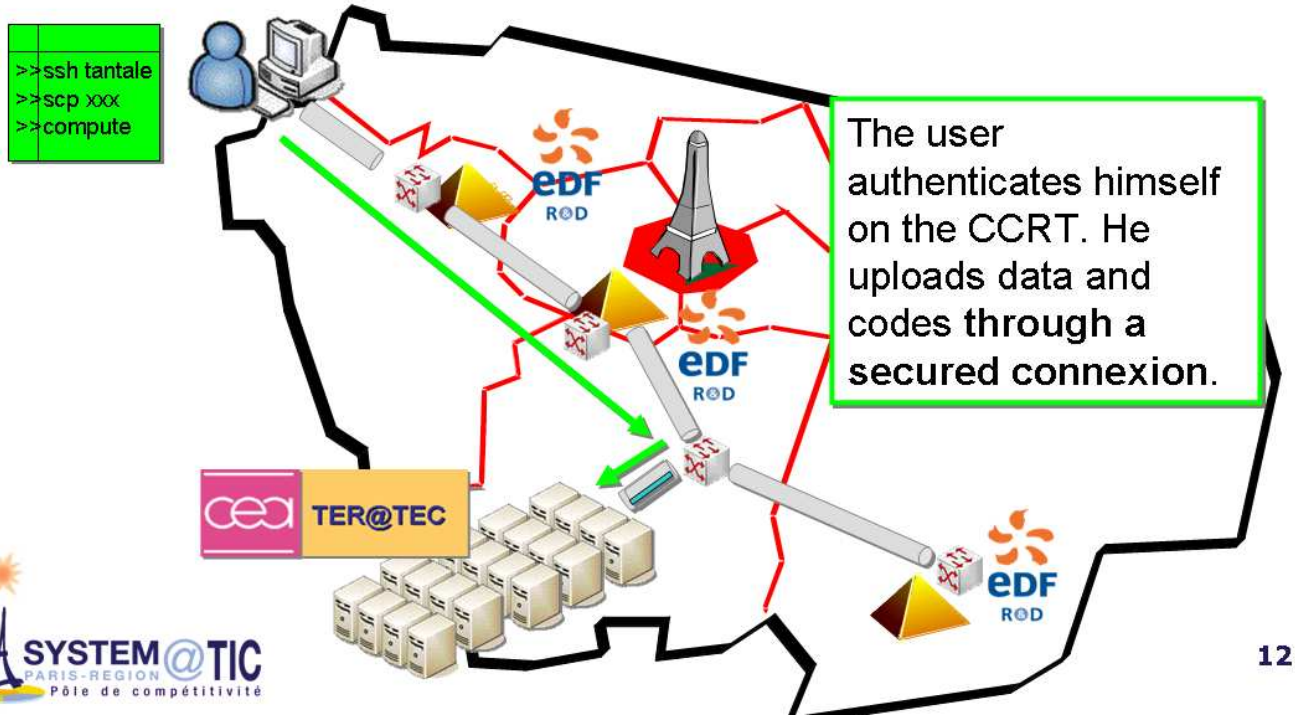



**IBM BlueGene/L**
1st european industrial supercomputer

Credits : EDF, courtesy of IBM

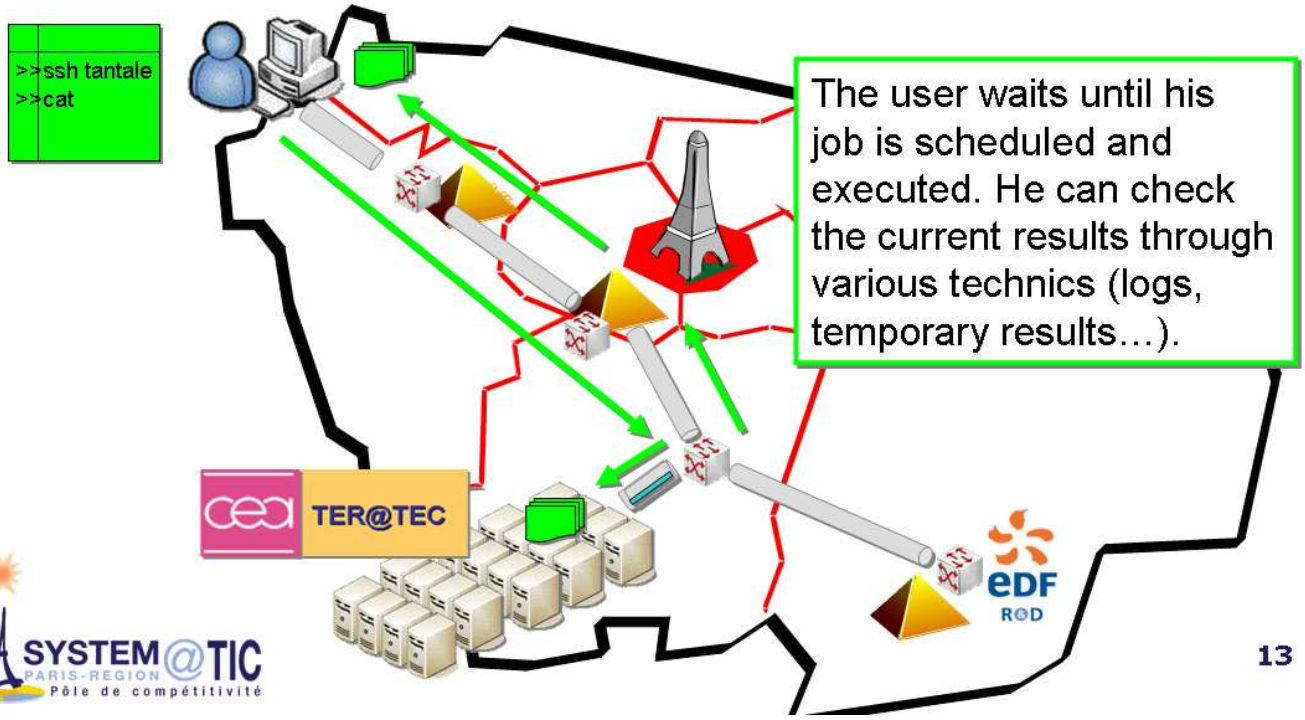
# Today EDF HPC Use Case

- **An example from the CFD world : everyday use of the CCRT HPC ressources**



# Today HPC Use Case

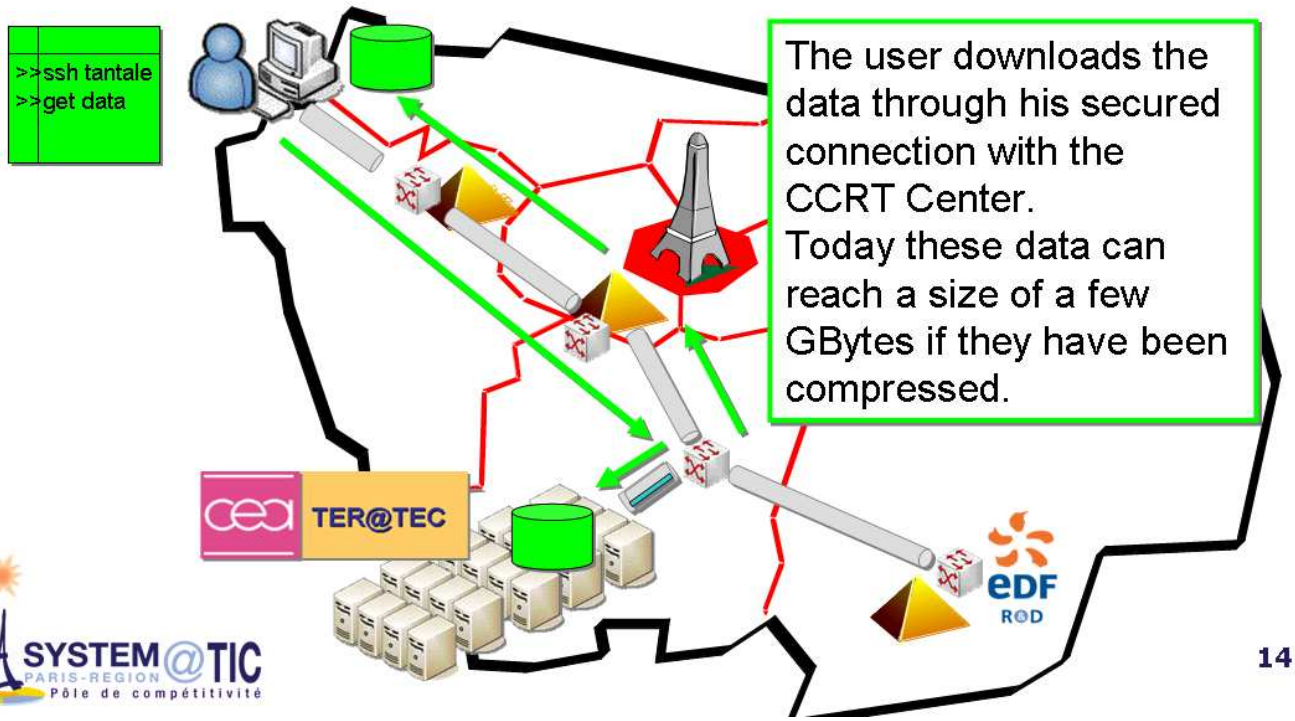
- Computation monitoring





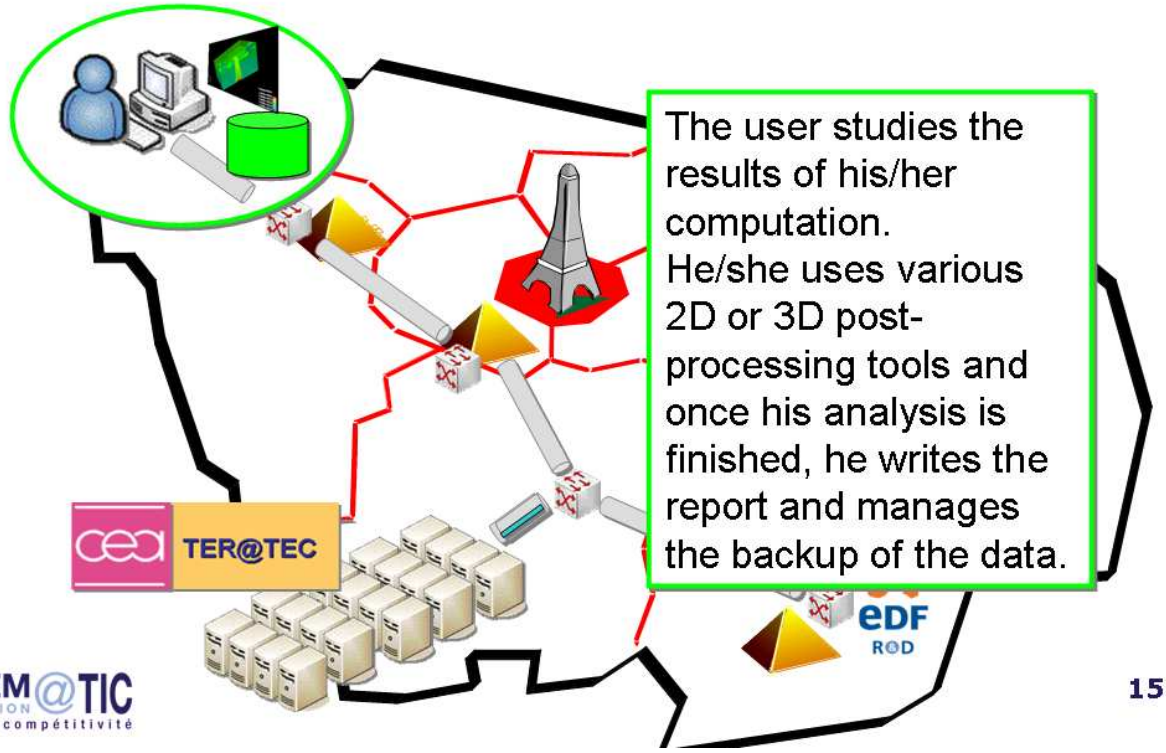

# Today HPC Use Case

- When the computation is finished…



# Today HPC Use Case

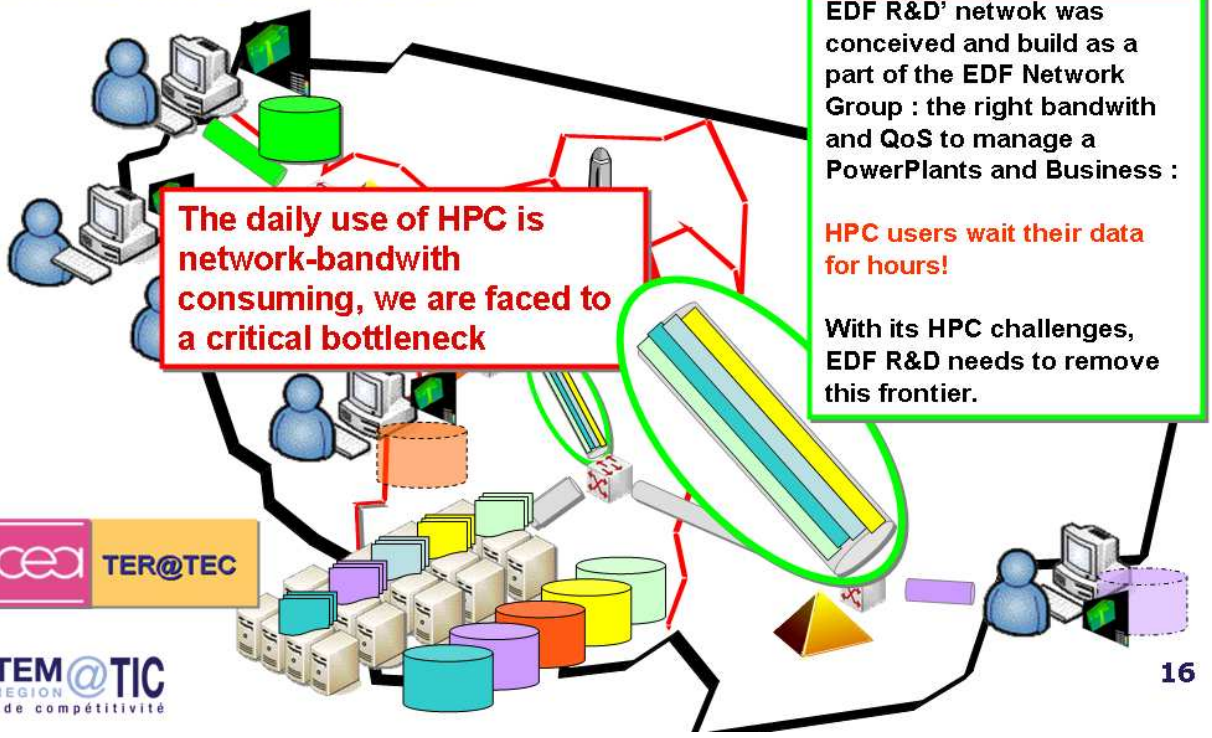
- Post-Processing on the user workstation





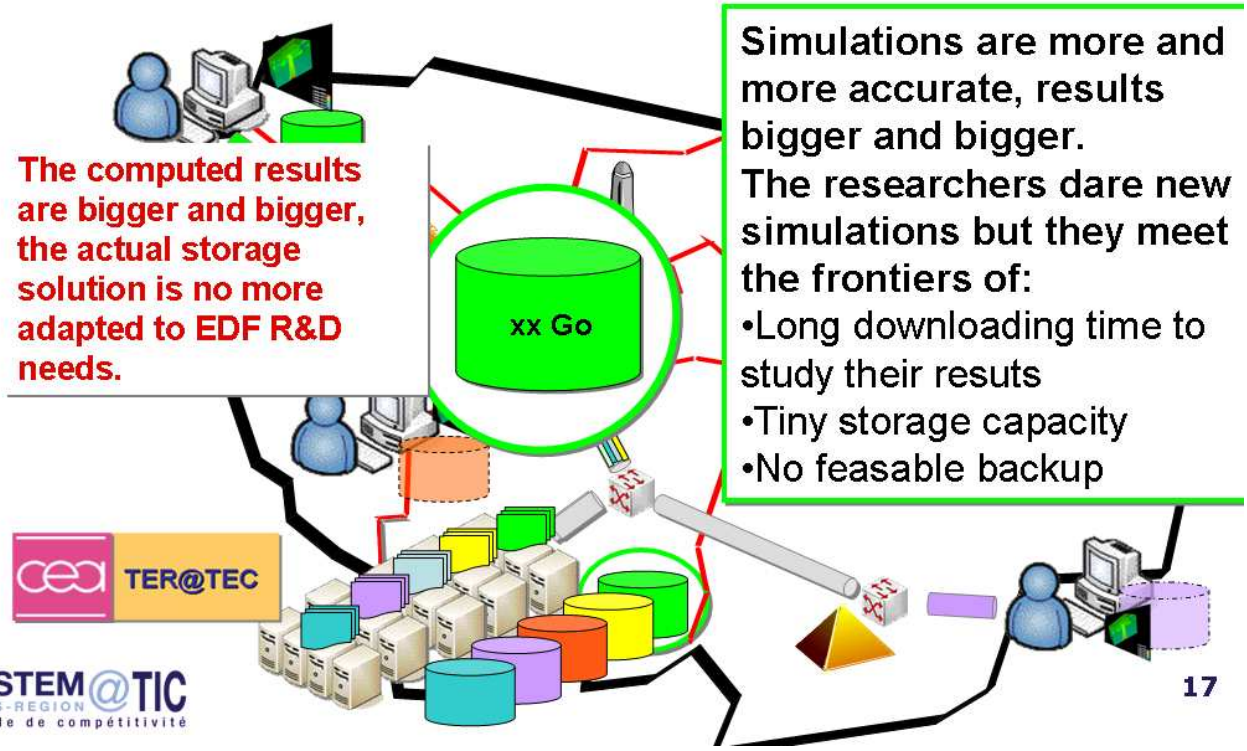

# But we met new frontiers (1)

- This is one example but daily activity at EDF R&D is around 600 such scenarii



## But we met new frontiers (2)

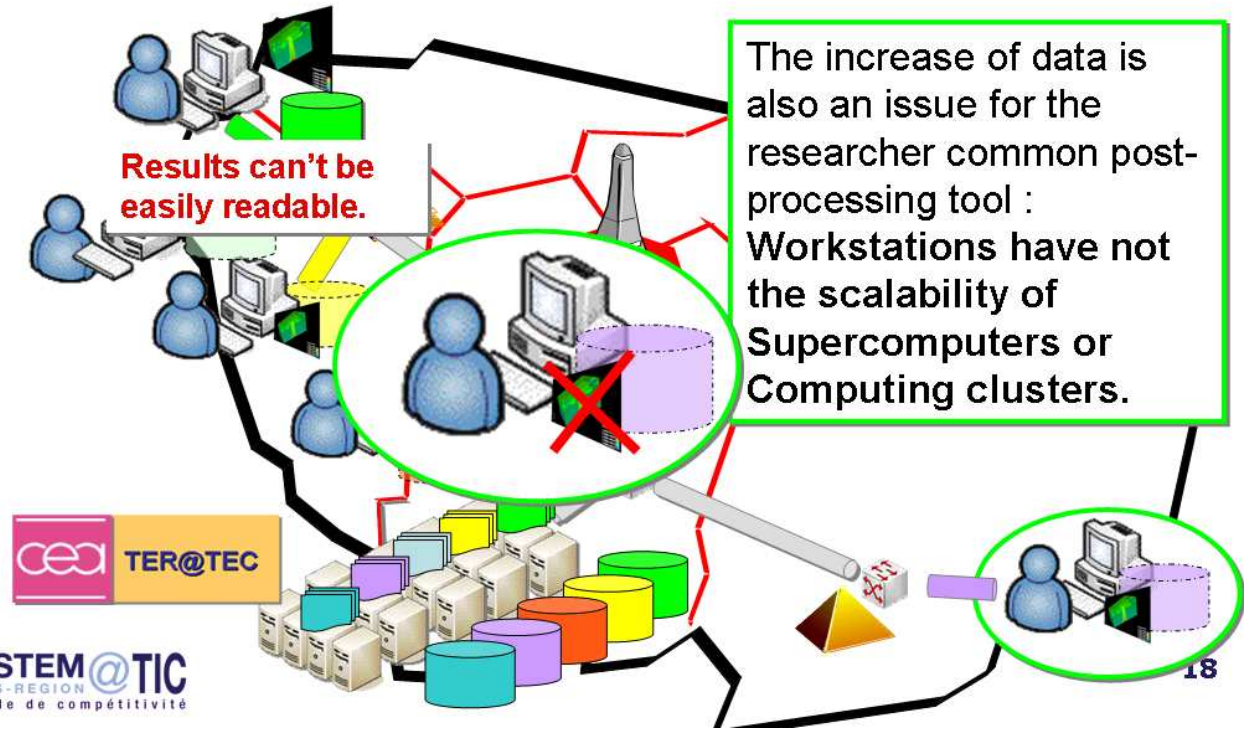
- Hom to manage these « Next-Day » simulations data?





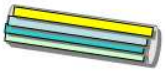
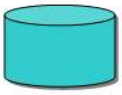

## But we met new frontiers (2)

- How to analyse these « Next-Day » data?



## Technological Bottlenecks

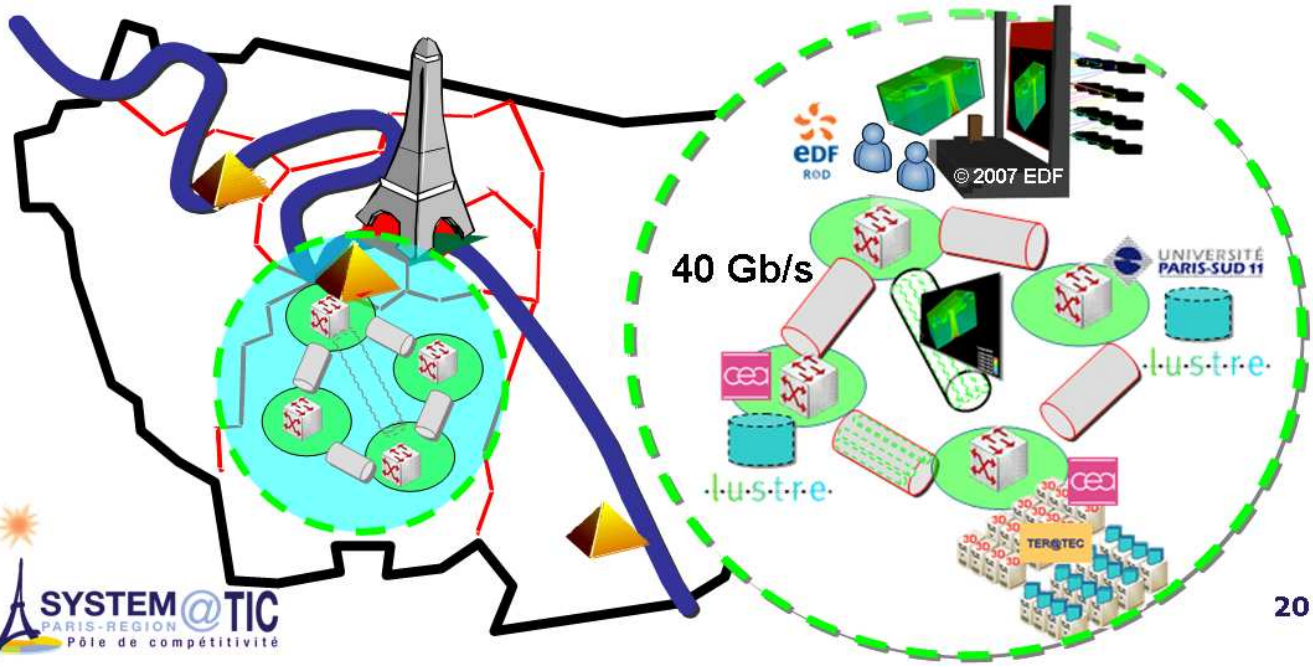
- To manage dozens of GBytes of simulations data for one user among hundreds implies to design and deploy a global solution to master the problems of :
  - **Networks (QoS, Bandwith..)**
  - **Storage and Backup**
  - **Analysis software and hardware ressources**
  - **Remote Collaborative expertise?**
  - Realtime Simulation Monitoring?




## A provocative proposal : the CARRIOCAS technical architecture

- **CARRIOCAS : 40 Gb/s for**
  - A Distributed Massive Filesystem (LUSTRE)
  - Remote High Performance ScientificVisualisation

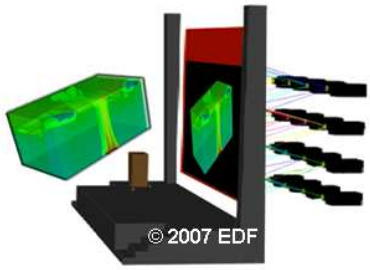


# Target

- **Which kind of users? All of them !**
  - Researchers : physicists, mathematicians, numerical analysis specialists
  - Experts and Engineers of EDF engineering Units for :
    - CAD, safety studies

  **Everybody who use daily**
    - HPC tools

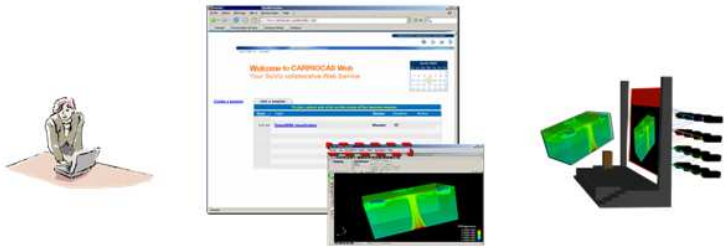
- **But new post-processing tools have to become User Friendly, user must not have to become viz experts**



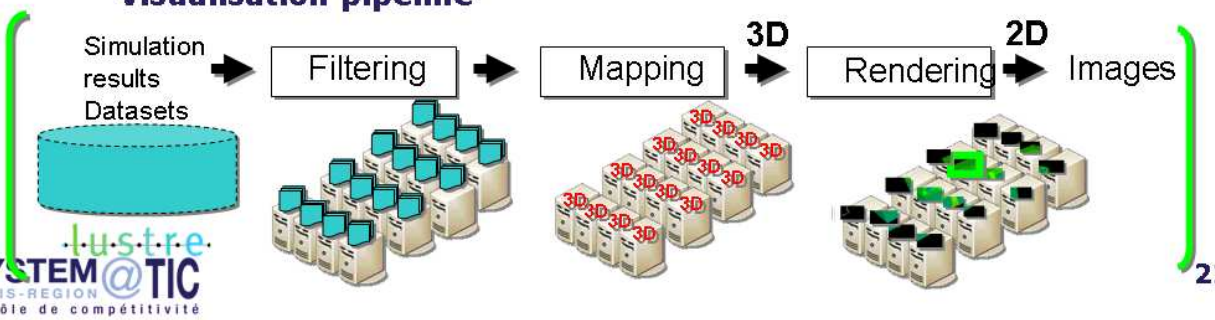



# CARRIOCAS objectives:

- A new use of High Performance Scientific Visualisation:
  - **The Convergence of two worlds : IT and HPC**
    - **Thanks to the easiest way to access to scientific visualisation services : VISUPORTAL**



    - **Automatic configuration of HPC ressources for the scientific visualisation pipeline**



# Part 2 : The first results of the CARRIOCAS teams : T0 + 12 month

The first VISUPORTAL prototype
First experimentions
First technical results for :
Lightweight streaming client (VLC), Scalability of Post-Processing techniques for large 3D scenes and High Resolution Displays

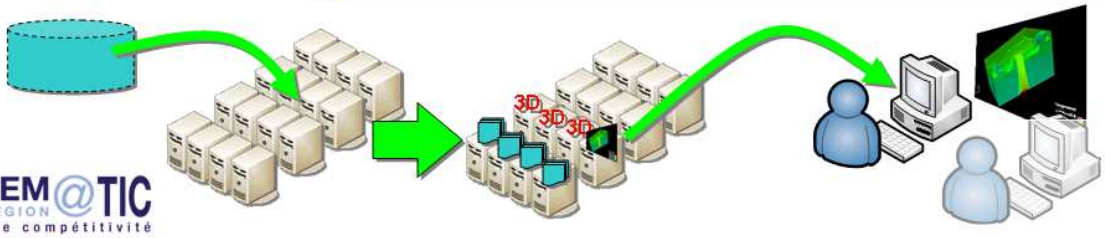




## The VISUPORTAL prototype

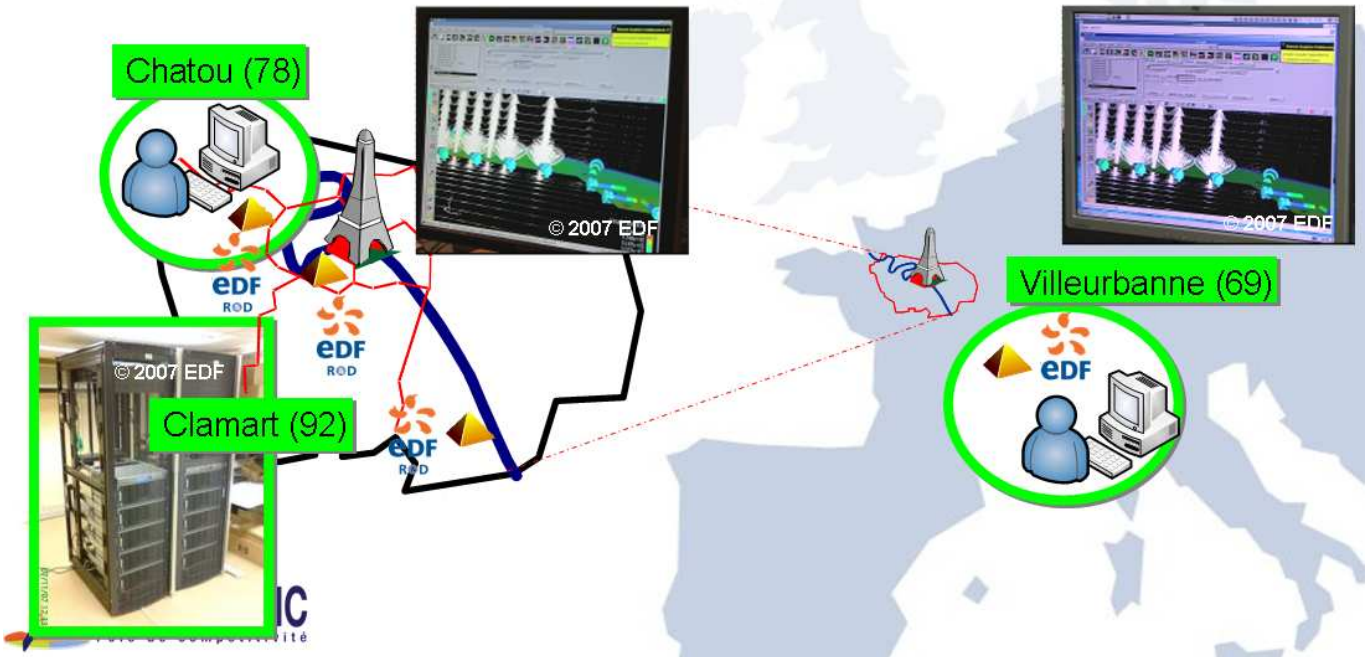
- A **VISU**alisation **PORTAL** by OXALYA
  - For booking and using Remote High Performance Visualisation ressources
  - With a first integration of a remote visualisation tool : HP Remote Graphics (HP RGS)
  - Conceived and tuned for the post-processing software EnSight with its various versions : standard, Gold, DR (Distributed Rendering)
  - Equiped with monitoring ressources : RAM, CPU, Network uses (HURRICANE © OXALYA)

- The User
  - Selects one of his datasets
    - **VISUPORTAL checks the data**
    - **Allocate the corresponding right ressources**
  - Invite (or not) his colleagues
  - Then joins the session and his job begins.



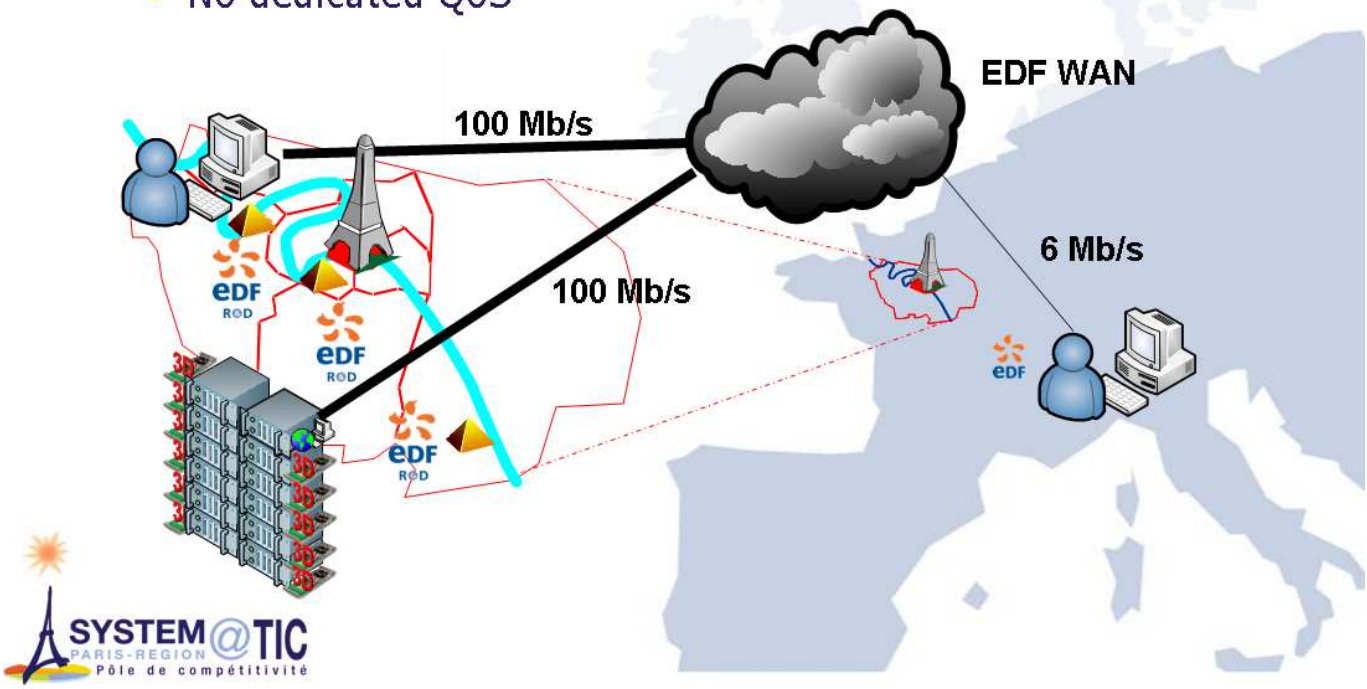
# Experimental & ergonomic REX 1/7

- The first VISUPORTAL prototype was deployed on 11 graphics nodes cluster at EDF Clamart in October 2007.
- Tested between EDF R&D and an EDF engineering Unit (500 km far).




# Experimental & ergonomic REX 2/7

- **EDF : A constrained WAN**
  - A narrow network bandwith with distant entities
  - No dedicated QoS

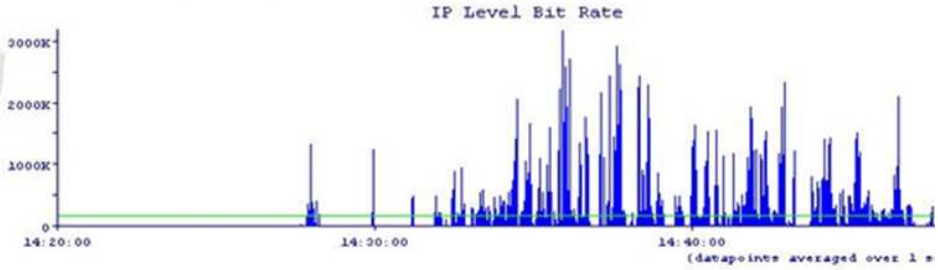


# Experimental & ergonomic REX 3/7

- **3 pairs of distant users** :
  - Researcher (EDF R&D) /Engineer (EDF)
- On **real EDF case studies** (nuclear safety studies)

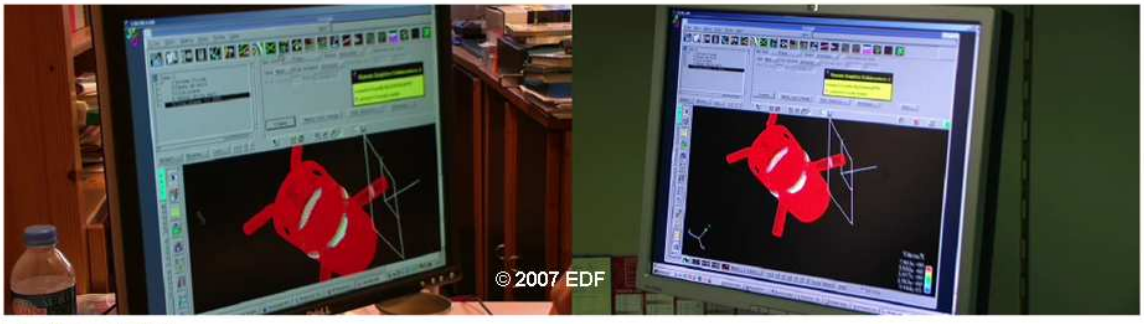

- Filmed and Networking measured/monitored on both sites
  - Two HD cameras,
  - Two Network traffic Analysers (Niksun NetVCR)

Credits : NIKSUN,Courtesy of J3TEL




# Experimental & ergonomic REX 4/7

- Short extracts of the video records of the experiment

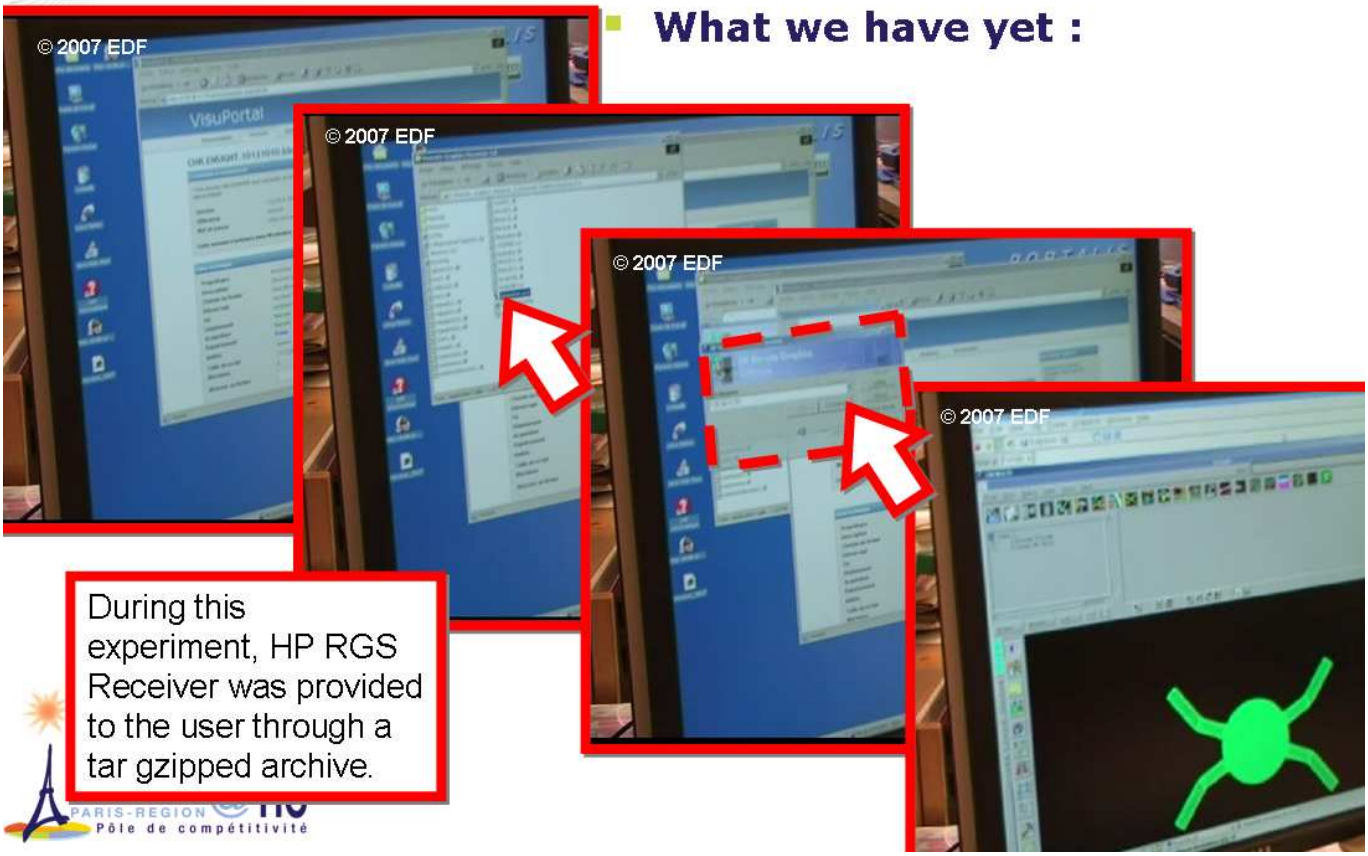
# Experimental & ergonomic REX 5/7

- **« Is it possible to keep it ? »**
  - The « experimental »users are definitely convinced by
    - the « easy of use » of the Visuportal system
    - The cluster performance of EnSight software
    - the performance of HP RGS (even if **the maximum measured network bandwith was 2 Mb/s** (peak) for RGS)
  - The users never notice that they were using a distant graphic cluster.
- **But… a few disappointments :**
  - No easy-login system to connect the remote visualisation tool to the distant linux cluster nodes
  - No easy way to deploy the remote visualisation tool for new users.
  - Not Firewall Friendly (dedicated TCP port : 42458)
  - Not enough intuitive Collaboration GUI



# Experimental & ergonomic REX 6/7

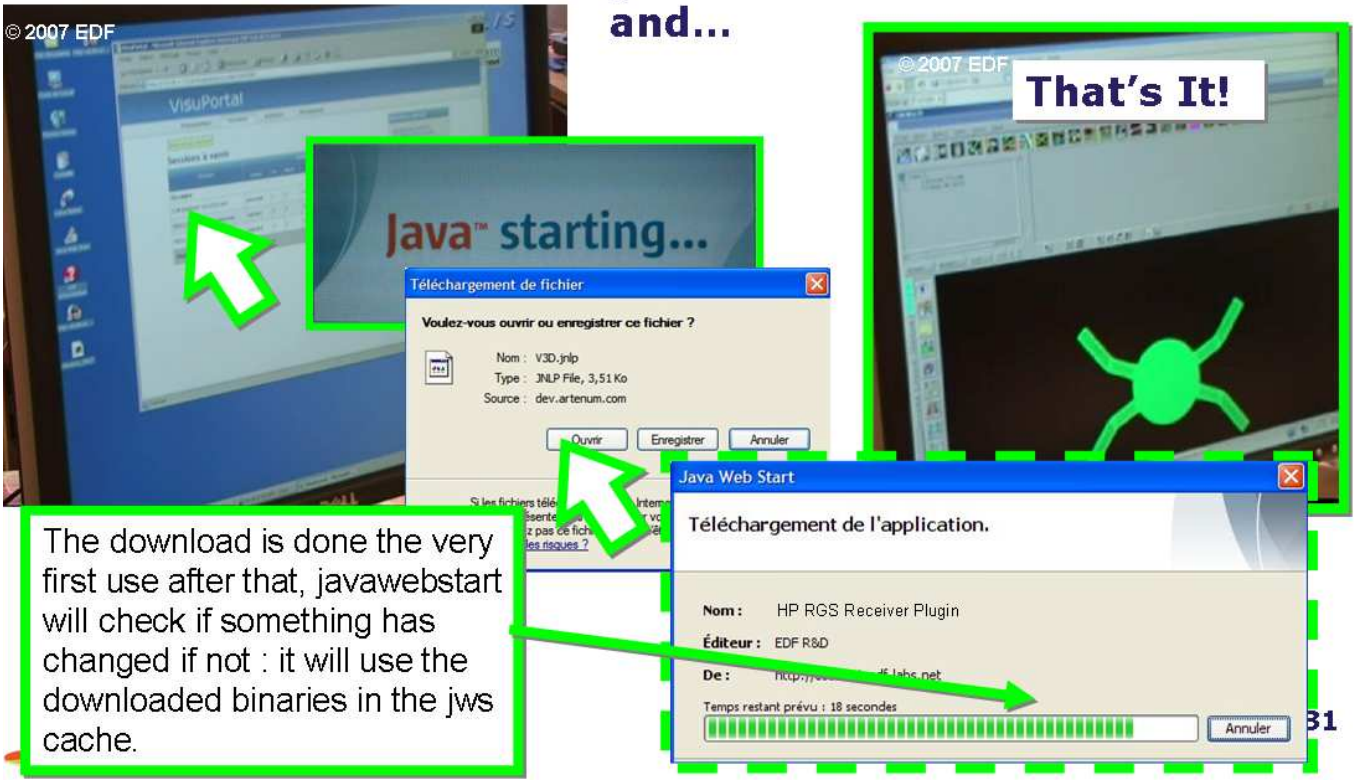
- **What we have yet :**




During this experiment, HP RGS Receiver was provided to the user through a tar gzipped archive.

# Experimental & ergonomic REX 7/7

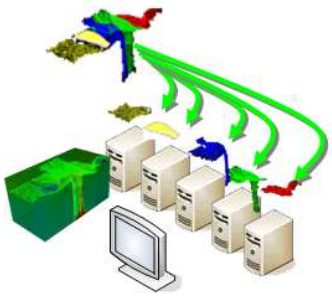
- **What the users want :just click on the session name and…**



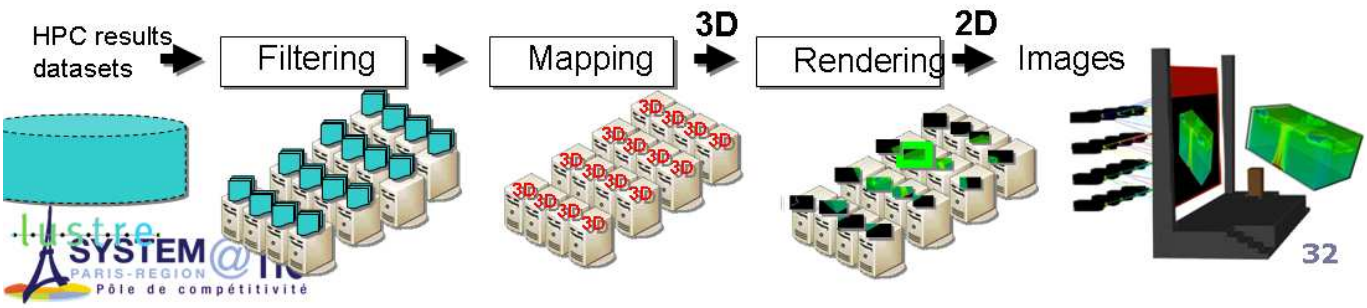

The download is done the very first use after that, javawebstart will check if something has changed if not : it will use the downloaded binaries in the jws cache.



# Scalability of visualization tools



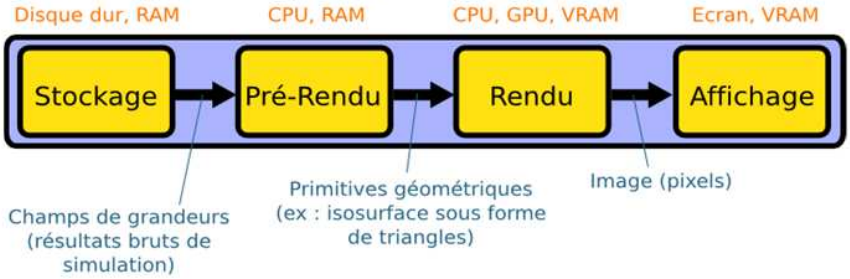
- **Scalability : a complex issue**
  - Datasets size (more « points »)
  - Display size (more pixels)



## Back-of-the-envelope analysis

- 40 Gb/s : how to consume bandwidth ?
- Straightforward approach of image transmission, no compression
  - 32 bits, stereo (x2)
  - 15 fps
  - Max image size of 40 G / 64 / 15 ~ 40 Mpixels…
    if 100% efficient – and data access/mapping/rendering is fluent !
  - MIRAGE CEA display is already 14 Mpixels
  - Of course compression can be used of other levels of transmission:
    - Data
    - Geometry

splitting the visualization pipeline at different stages

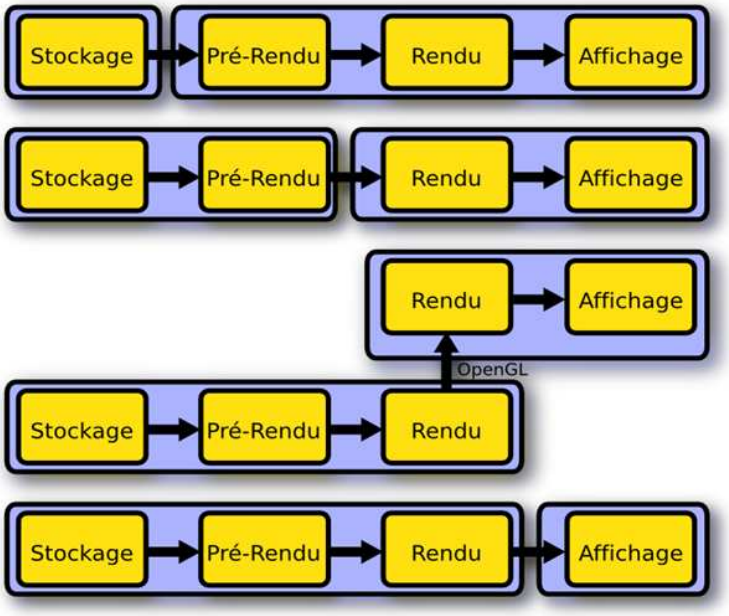





## Large scale visualization

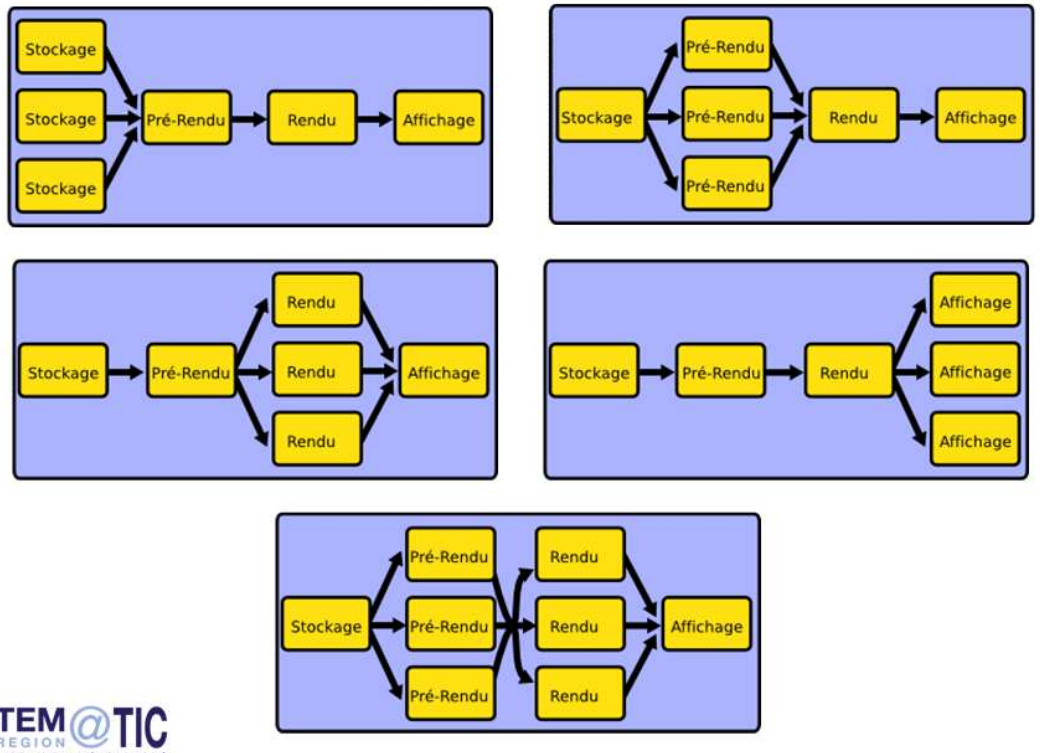
- 2 driving parameters
  - Datasets size
  - Display size
  - … and an output parameter = 'fps'
- Parallelism is a common answer to deal with these complexity factors
  - Datasets => more "data management processes"
  - Pixels => more " rendering processes"
  - Not the ultimate approach (you can be smarter than brute force "divide and conquer") but it is quite straightforward and general-purpose enough

## Viz pipeline possible distribution



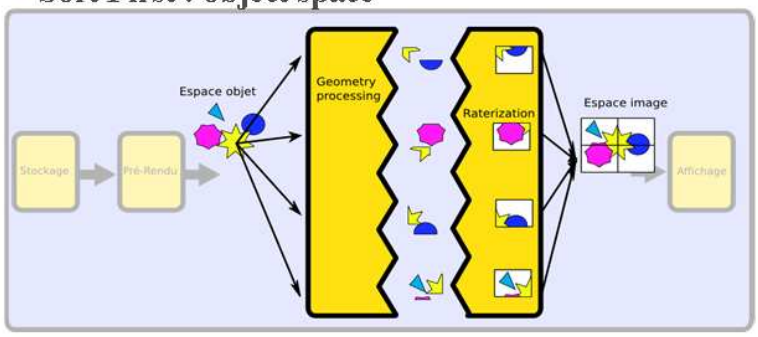



## Each stage can be "locally" parallelized

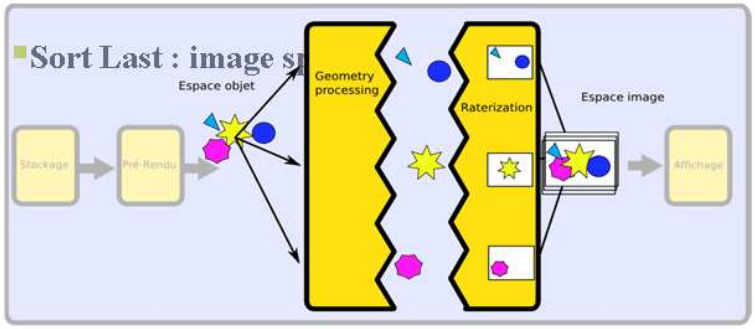


## Parallel rendering reminder / compositing

- **Sort First : object space**



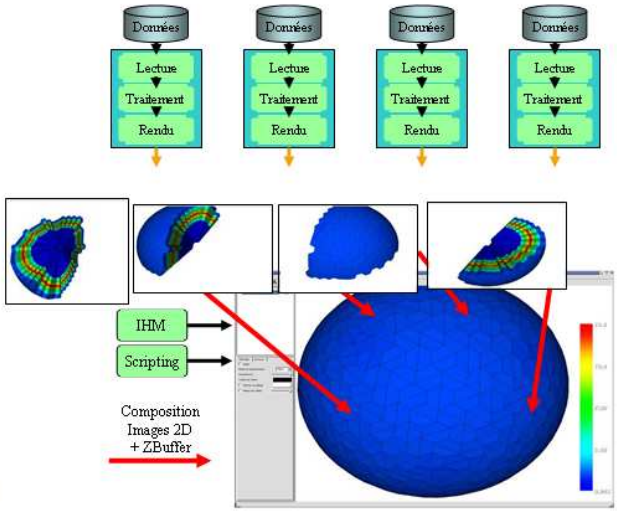

Scalable w.r.t. resolution



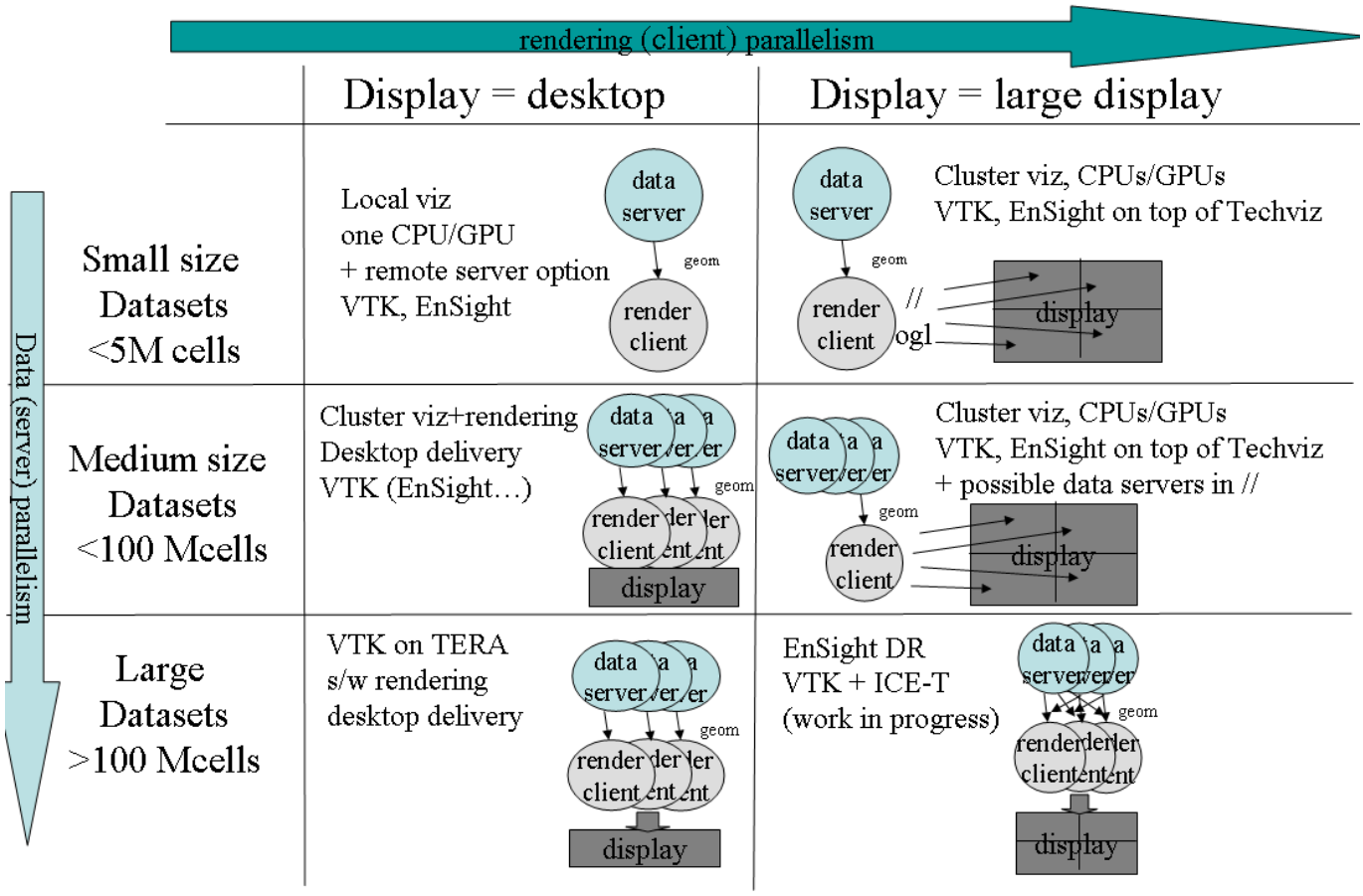

Scalable w.r.t. dataset (geom) size

## CEA/DIF experience

LUSTRE everywhere (TERA)…
VTK, EnSight
On clusters and large displays
"Weakly remote"

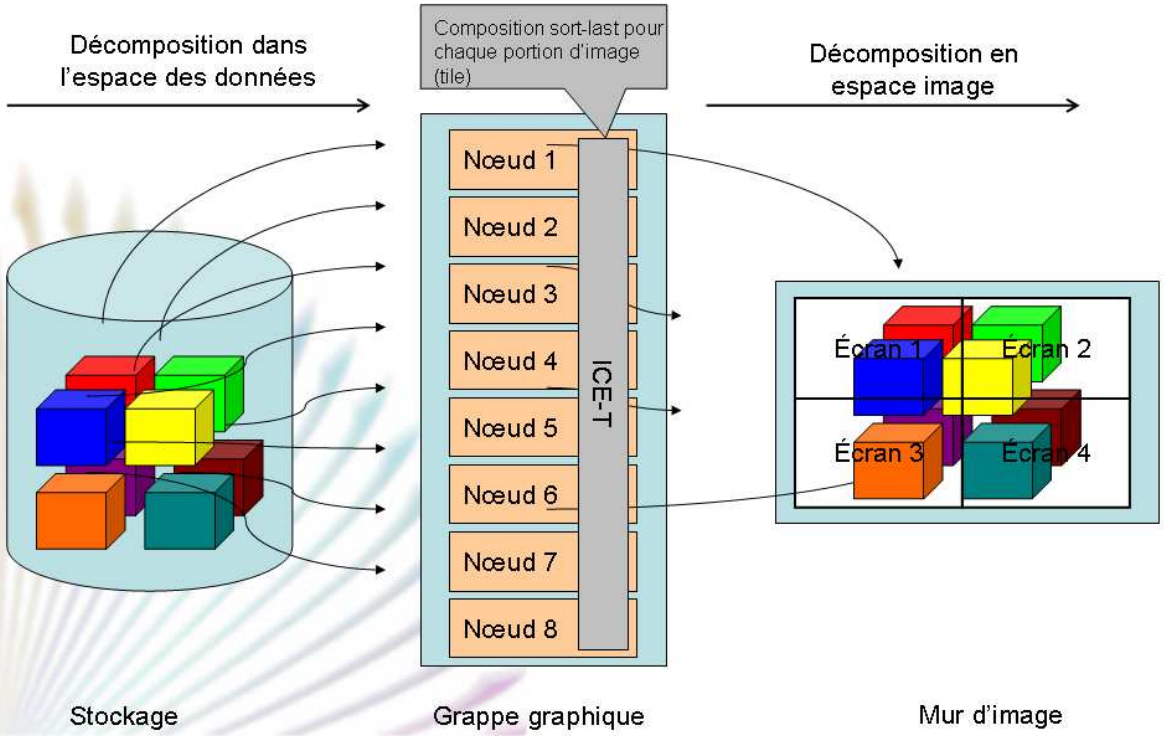







CARRIOCAS

## Hydrid SF/SL : ICET-T limited to VTK (pull data-flow model)



## Overall approach – WP4

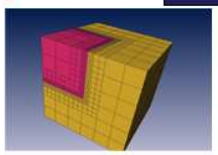
- Limited manpower and strong concern of perennity and independence
- Use:
  - existing software standards
  - open source components

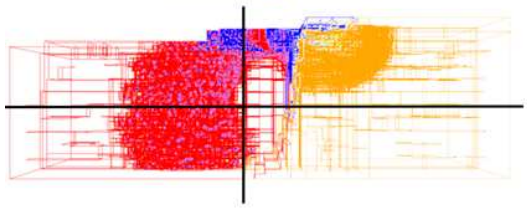
  as much as possible
- This is not in contradiction with the usage of proprietary software
  - as long as it can be mixed with open components

- 2007 = benchmarks, prototypes on small cluster/tiled display
- 2008 = consolidate, connect with LUSTRE and network
- 2009 = deploy and evaluate

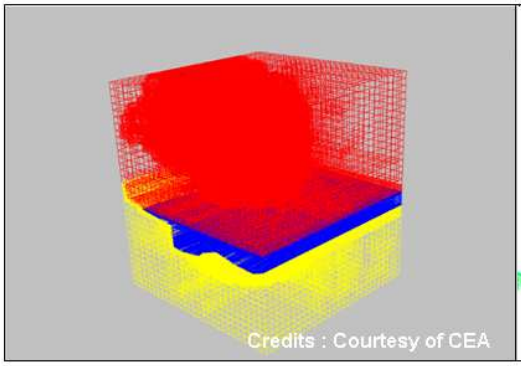


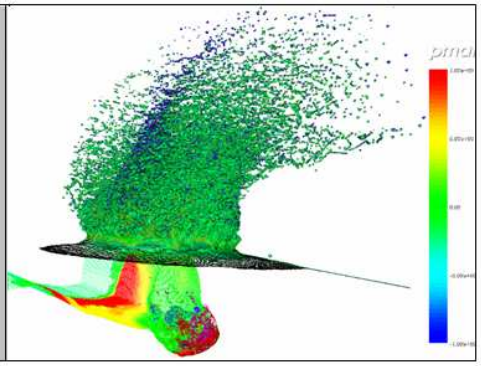
## CEA "use case" (basic benchmark for parallel viz)



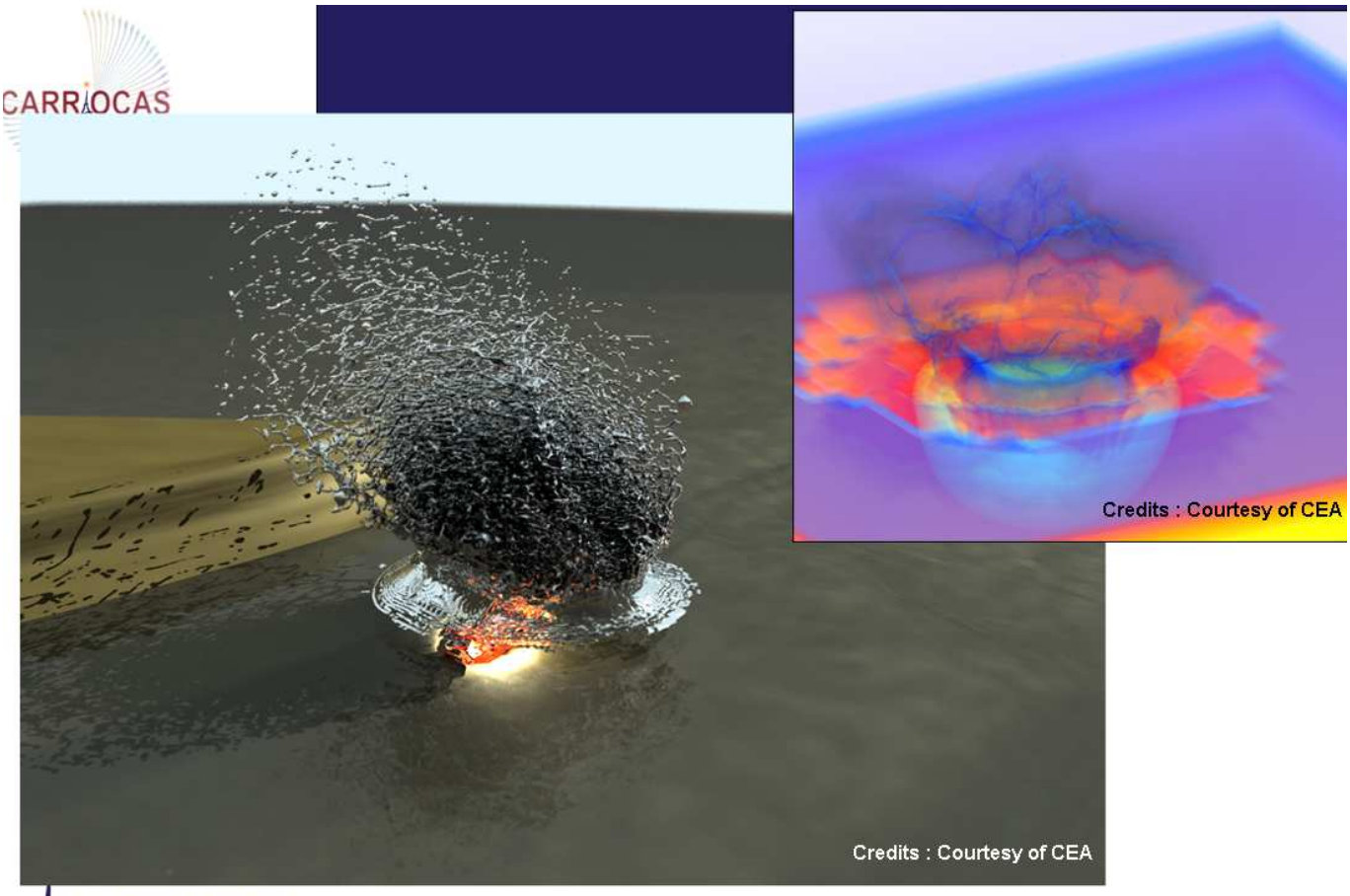


- A typical CEA parallel simulation : "Meteor" dataset
  - AMR, cartesian – considered as non structured (generic CEA concern)
  - 15 to 120 Mcells
  - 64 to 96 domains (mesh decomposition)



Credits : Courtesy of CEA






## Very pragmatic focus and choices

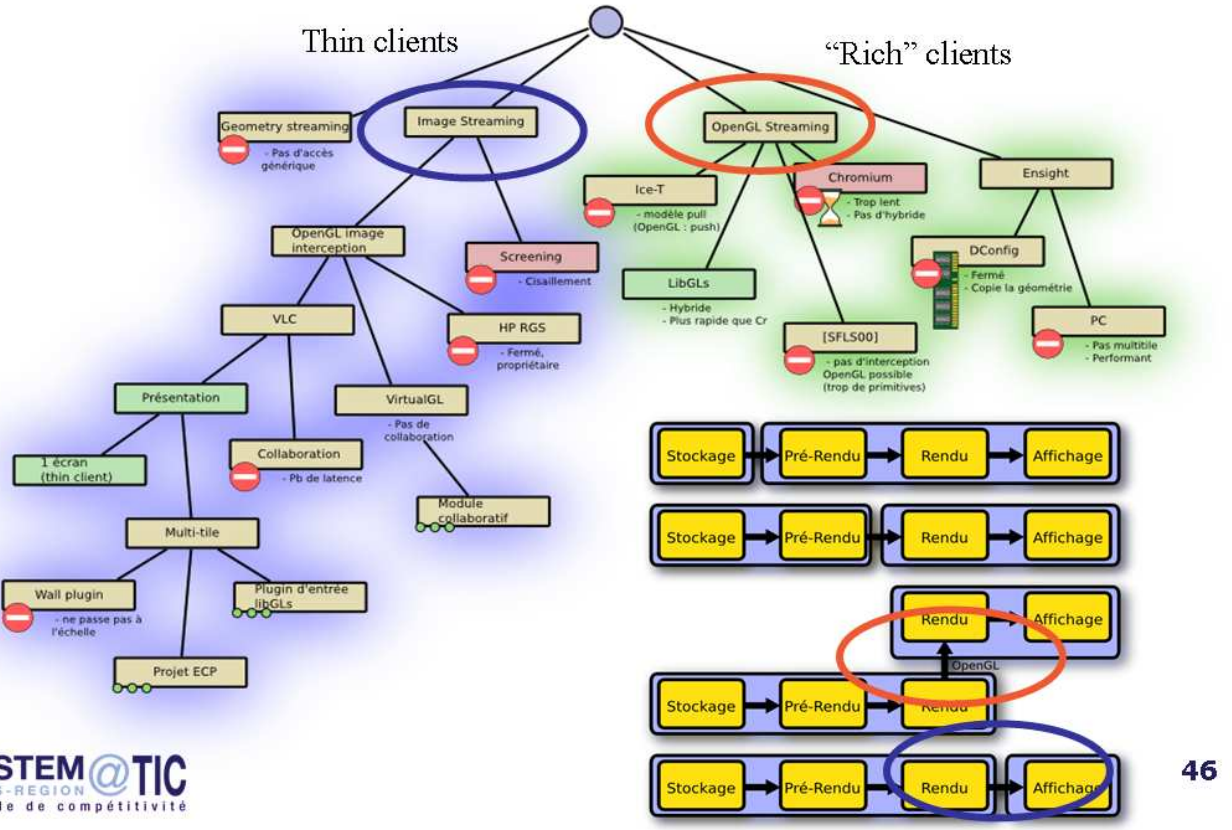
- General purpose existing packages, several "fairly good ones"
  - VTK / PARAVIEW
  - EnSight
  - AMIRA
  - VisIt…
  - Quite strong intersection but not strictly equivalent
- Focus on common denominator already used at CEA and EDF
  - EnSight
  - And VTK as a common kernel to PARAVIEW, CEA own developments - and possibly VisIt

## What about "middleware"?

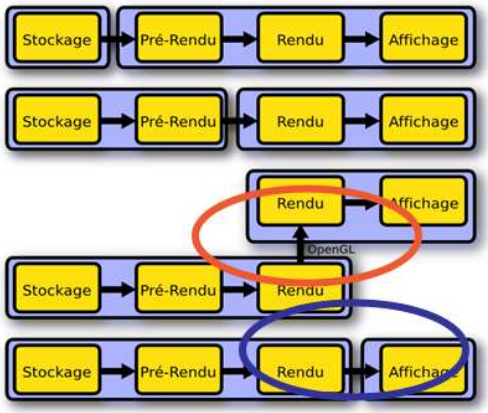
- Lower level layers able to parallelize / distribute rendering
- Either compositing, OpenGL interception or image streaming layers
  - OGL
    - Cr (Chromium)
    - Techviz (widely used in "local" production on CEA MIRAGE display)
    - …
  - Compositing
    - DVIZ
    - Equalizer
    - OIV ScaleViz…
  - Image streaming
    - SGI OpenGL VizServer ("rebirth" with SGI Visual Supercomputing)
    - IBM DCV/RVN
    - HP RGS
    - Sun Shared Visualisation
    - VLC ?
  - Only Cr and Equalizer are open source
  - Cr comes bundled with EnSight DR => try it…
  - We focused on this level of OGL or image remote articulation (genericity / transparency)



## CEA experiments…



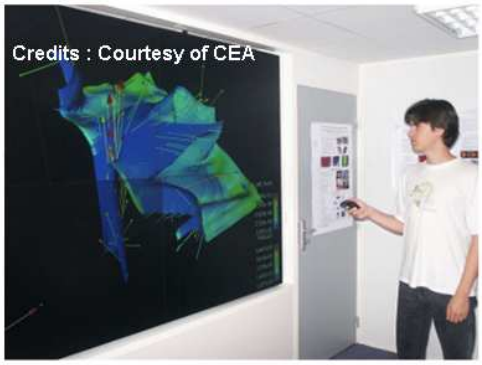
- Parallel data access and pre-rendering
  - In charge of the application
- Generic approaches, application independent
  - And a good location to consume bandwidth…



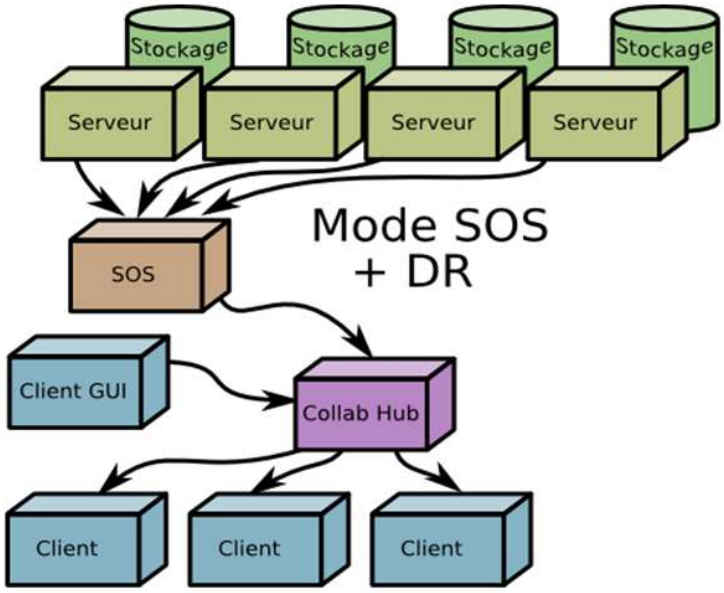


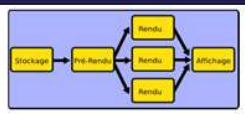

## Preliminary setup : parallel visualization

- EnSight DR evaluation : with support of DISTENE at TER@TEC – on TER@TEC visualization reseach facility

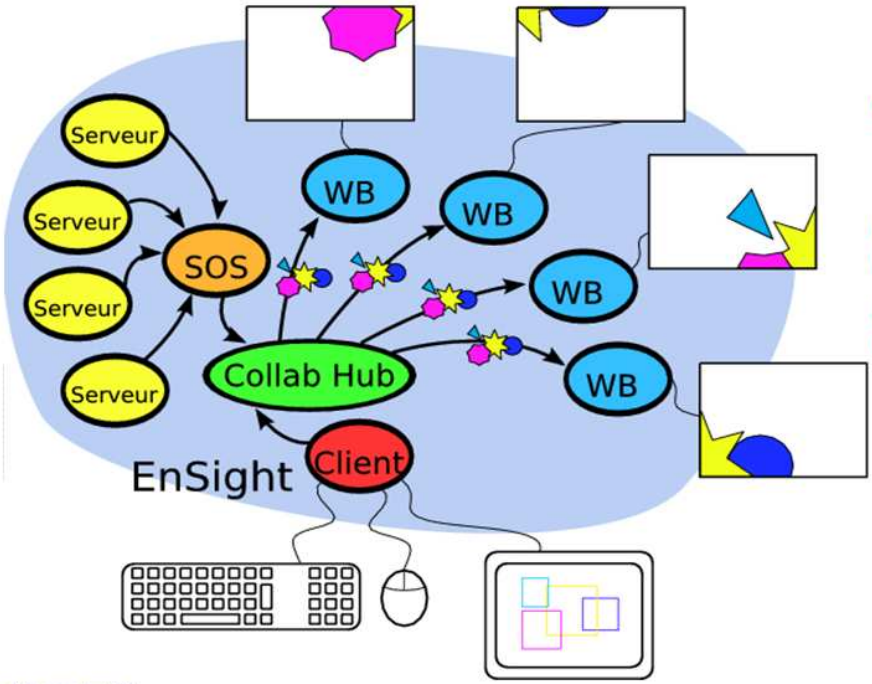



+ 8 node “small” graphics cluster



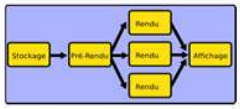



## Parallel rendering, DCONFIG mode

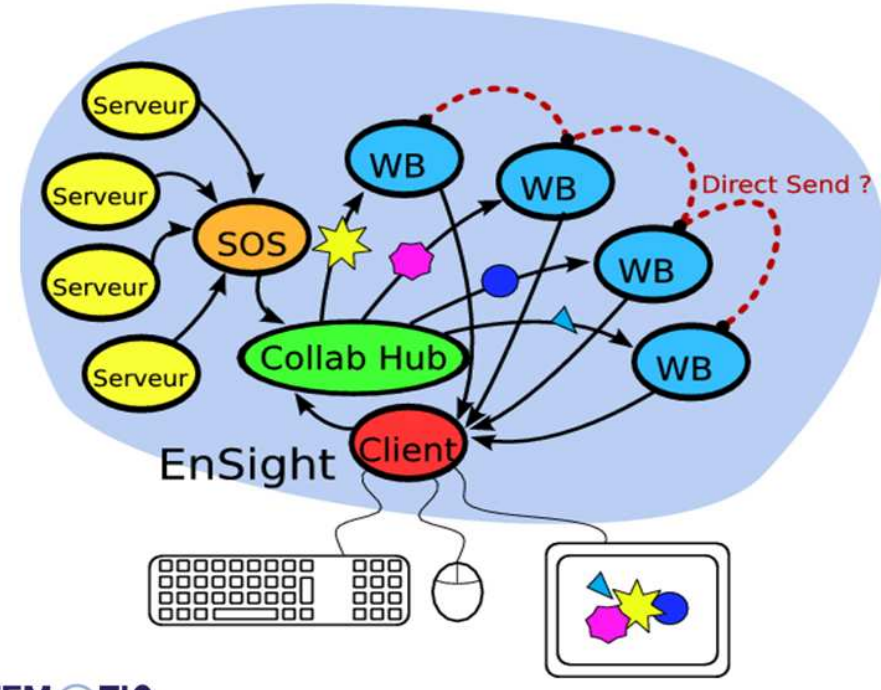



- Géométrie dupliquée sur tous les noeuds WB
- Sort-First (passe à l'échelle en résolution)
- Occupation mémoire totale linéaire en fonction du nombre d'écrans (tiles)
- Temps de rendu limité par la capacité de rendu d'une machine

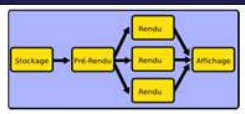
EnSight DR



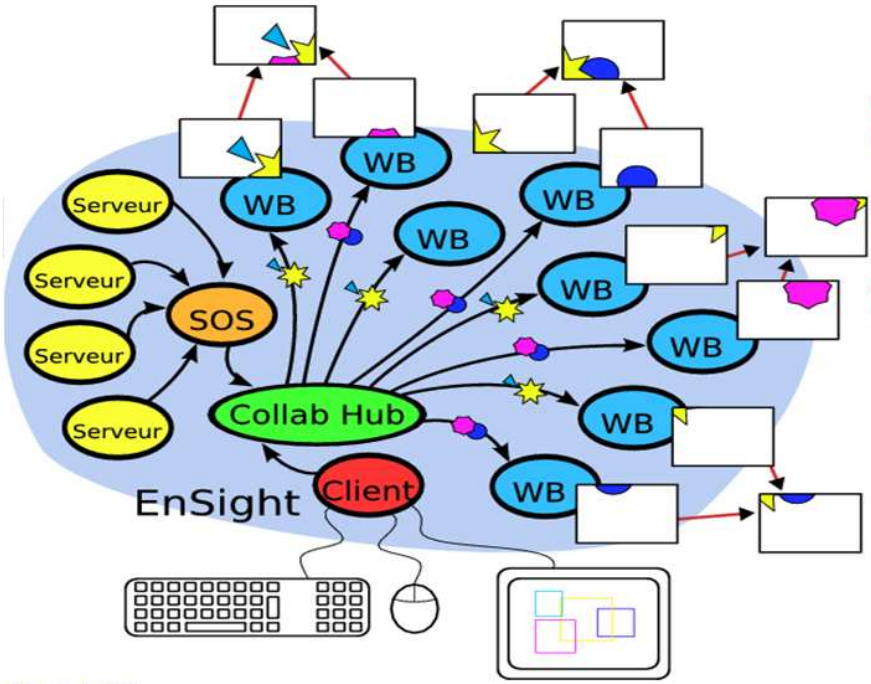

## Parallel rendering, PC mode




- Géométrie distribuée sur tous les noeuds WB
- Sort-Last (passe à l'échelle en complexité)
- Occupation mémoire totale fixe (la même que sur 1 seule machine)
- Temps de rendu limité par le réseau

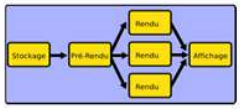



## Parallel rendering, DCONFIG WH mode

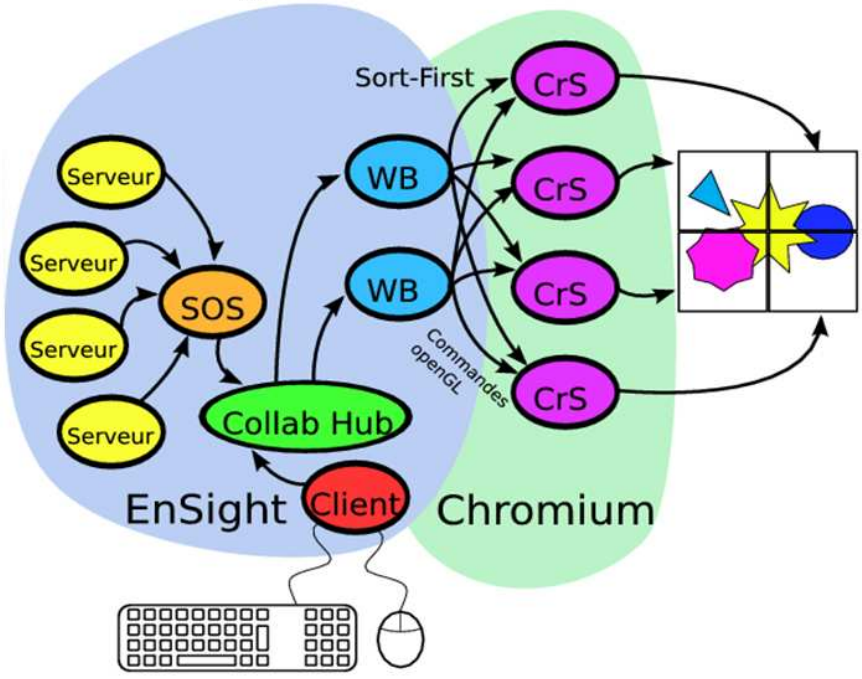



- Géométrie dupliquée sur tous les groupes de noeuds WB (distribuée au sein d'un groupe)
- Sort-First + Last (passe à l'échelle en complexité et en résolution)
- Occupation mémoire totale linéaire en fonction du nombre d'écrans (tiles)
- Temps de rendu limité par le réseau

EnSight DR




## Parallel rendering, Chromium mode

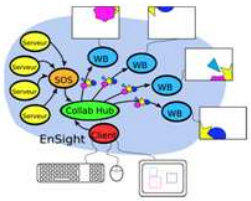


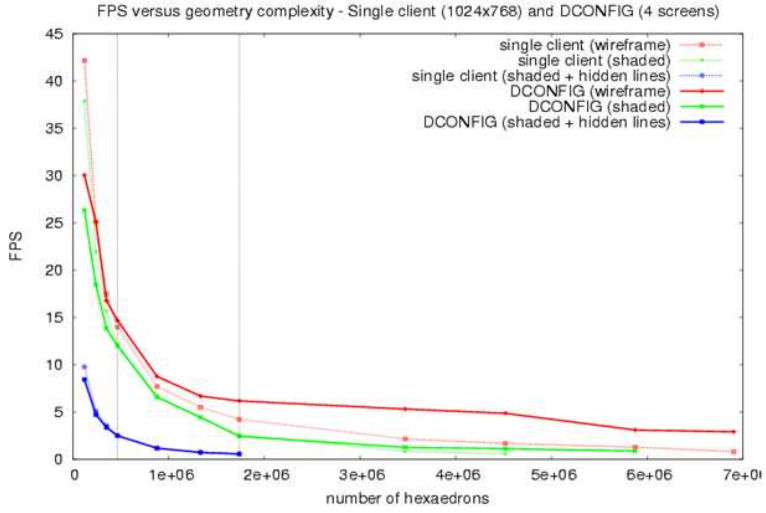

- Géométrie distribuée
- Sort-First (passe à l'échelle en résolution)
- Occupation mémoire totale constante
- Temps de rendu limité par la capacité de rendu d'une machine et par le réseau

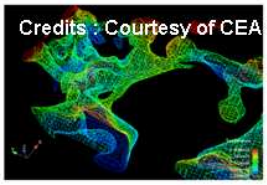
CARRIOCAS

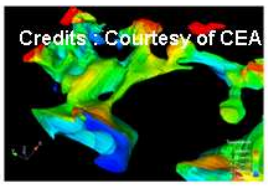
# Benchmarks

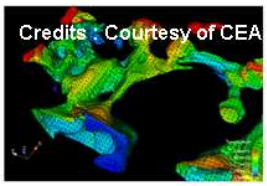
## Benchmarks, DCONFIG



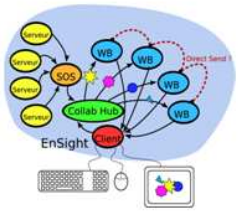



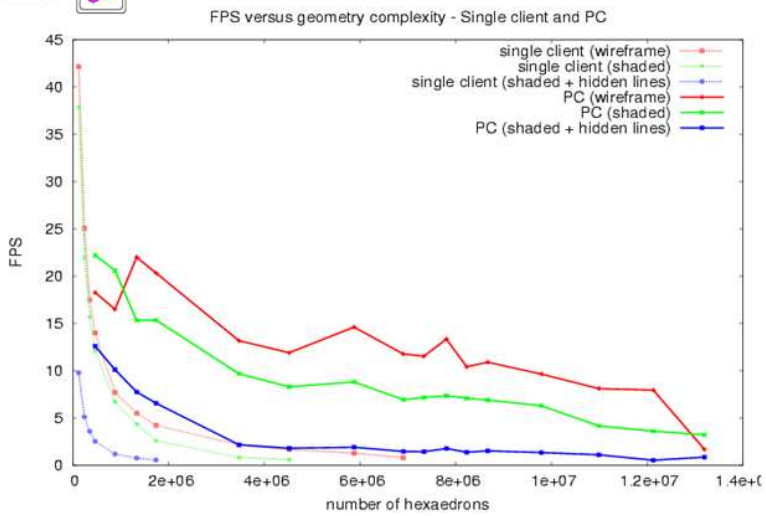

SYSTEM@TIC PARIS-REGION Pôle de compétitivité

CARRIOCAS

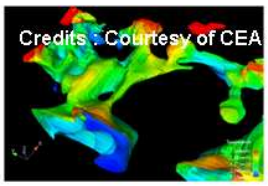
# Benchmarks

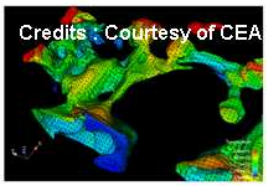
## Benchmarks, PC



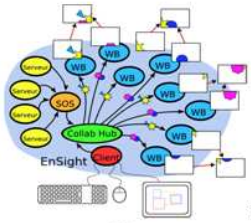


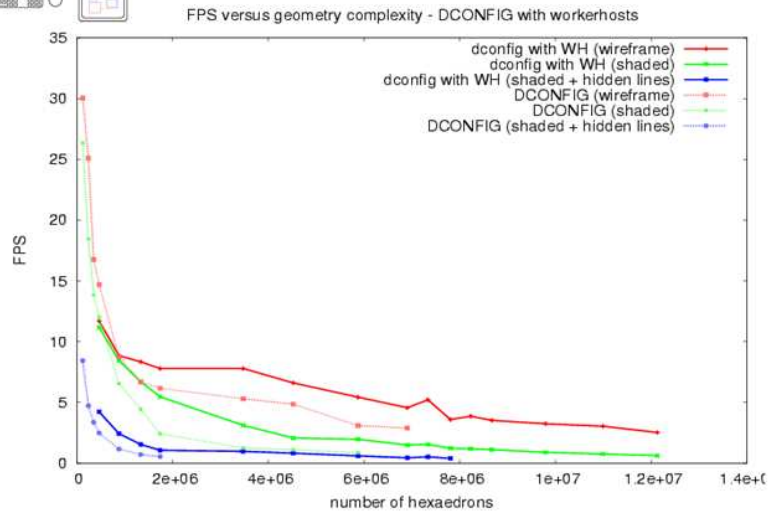


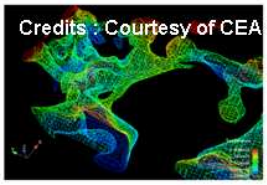



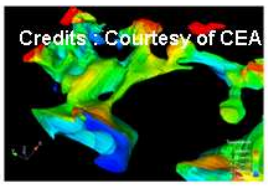

SYSTEM@TIC PARIS-REGION Pôle de compétitivité

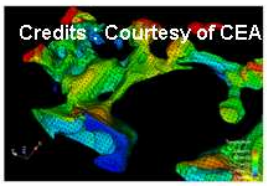
## Benchmarks, DCONFIG V



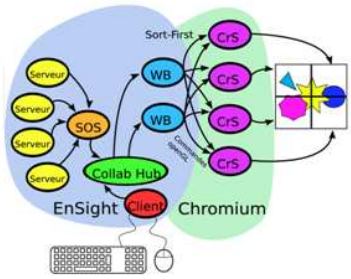



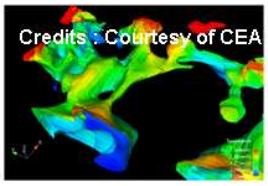



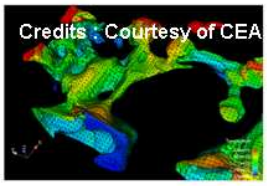

Benchmarks

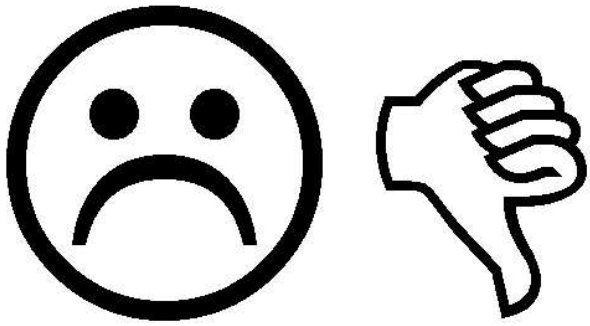
## Benchmarks, Cr



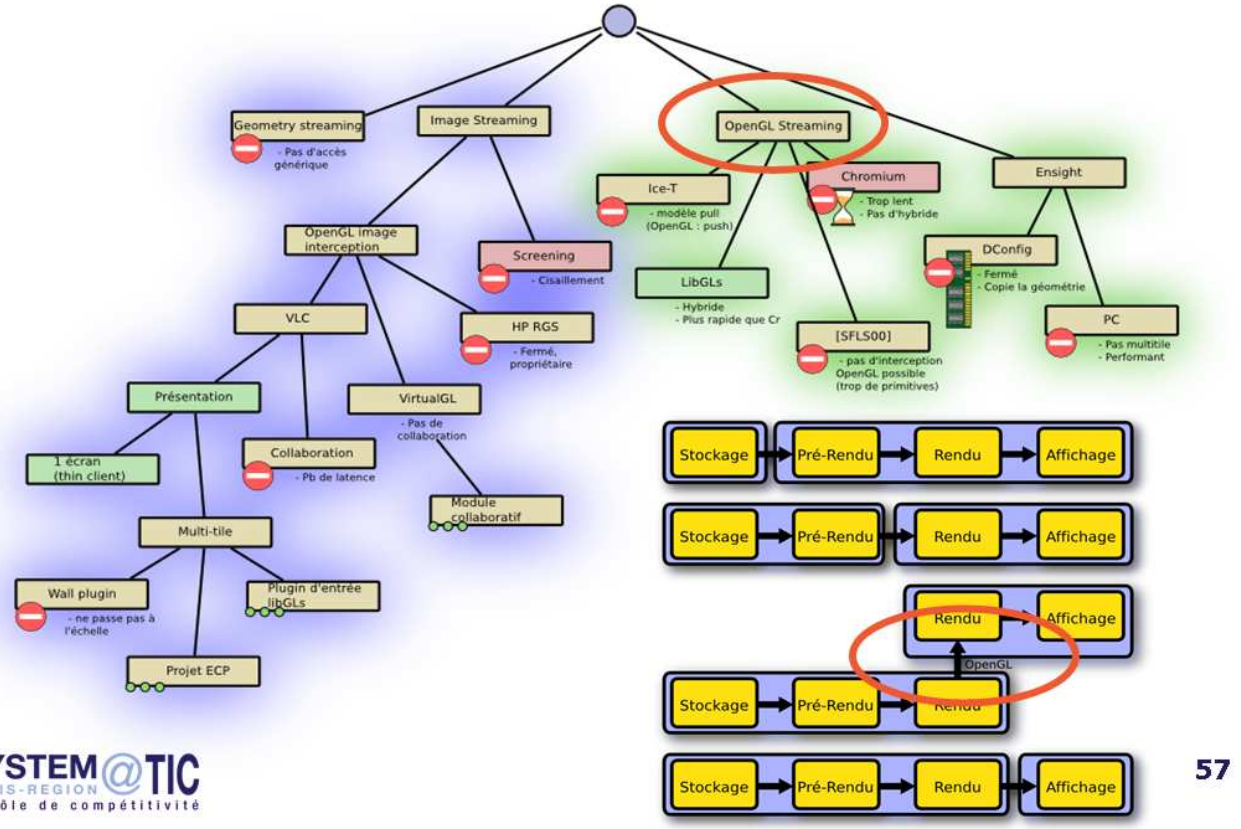




## CEA experiments...

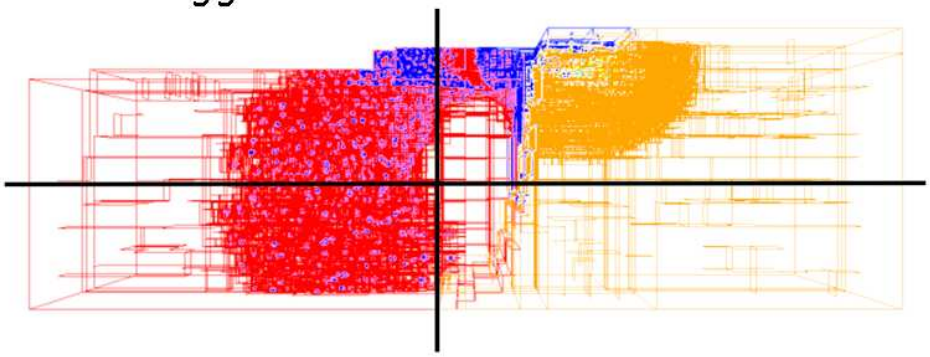





## libGLs

Ensight DR:

- Closed / proprietary
- Total RAM usage linear w.r.t. number of tiles
  - Meteor: 38.4 Go RAM for 4 tiles (56 domains)
- Chromium: the basic reference, very general, but slow and bugged

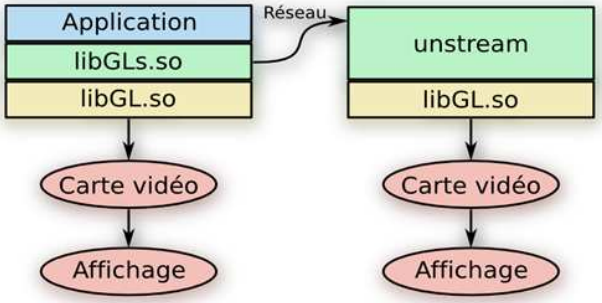


=> libGLs prototype, ligthweight interceptor, hydrid sort-first/last

# libGLs

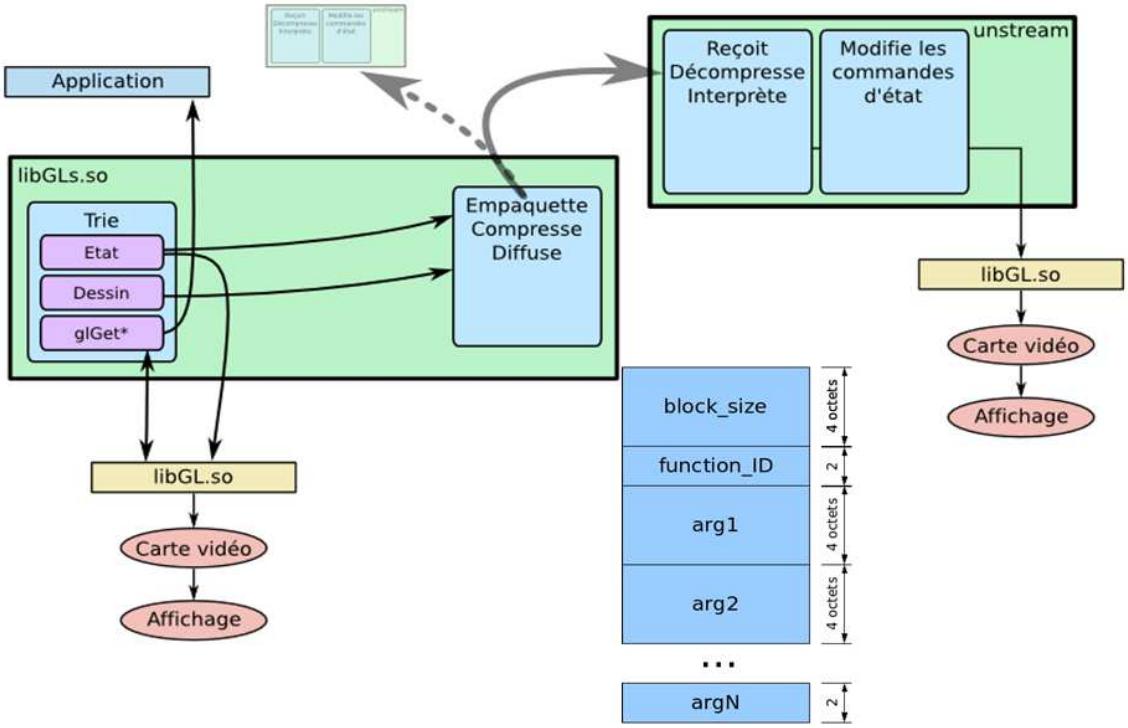
Goals

- Open source: GPL components
- Transparency: compliant with EnSight, but also other viz packages

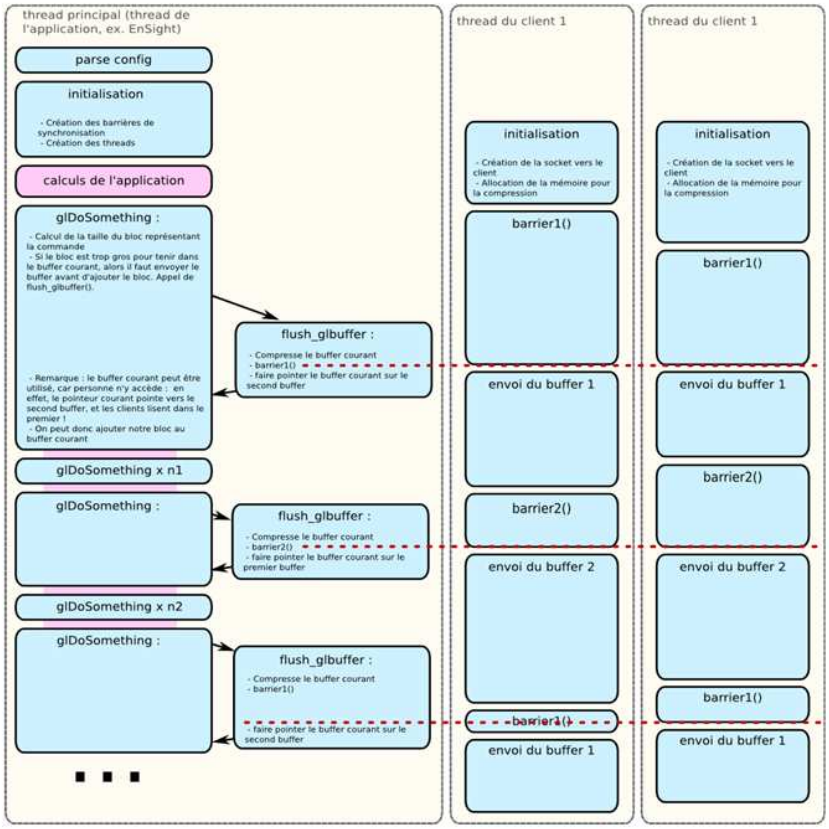



- RAM friendly: streaming ≠ data copy
- Performance: less general than Cr but better suited to our problem

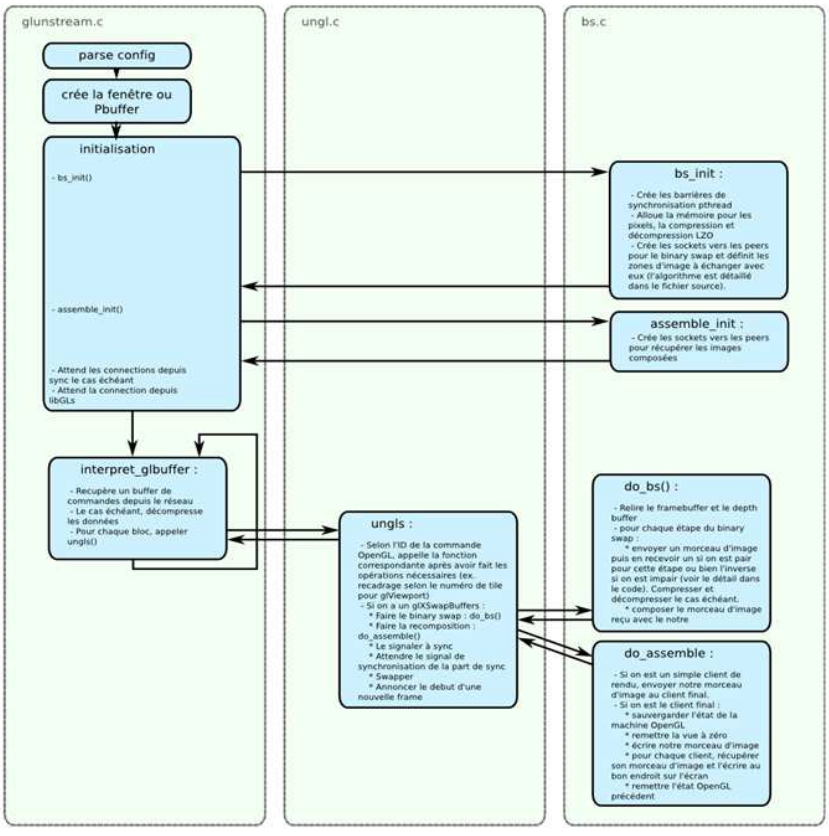
# libGLs : command management



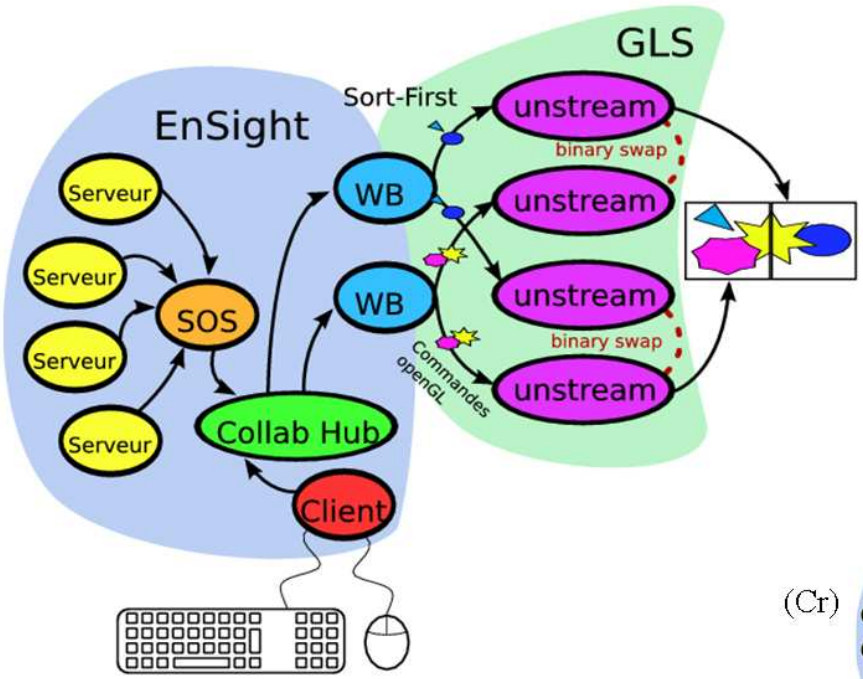
# LibGLs (libgls.so)




# LibGLs (libgls.so)

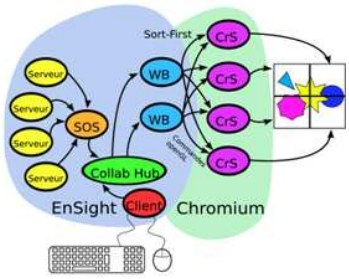


# A ligthweight OpenGL interceptor



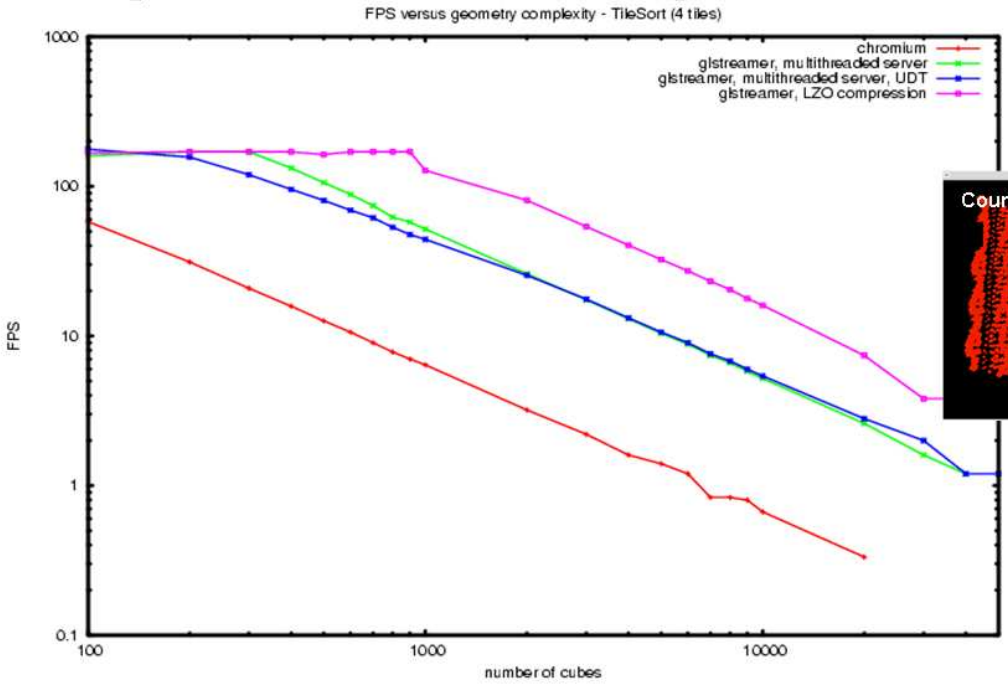

- Géométrie distribuée (par EnSight)
- Sort-First + Last (passe à l'échelle en complexité et en résolution)
- Occupation mémoire totale constante (approche flux)
- Temps de rendu limité par le réseau

(Cr)

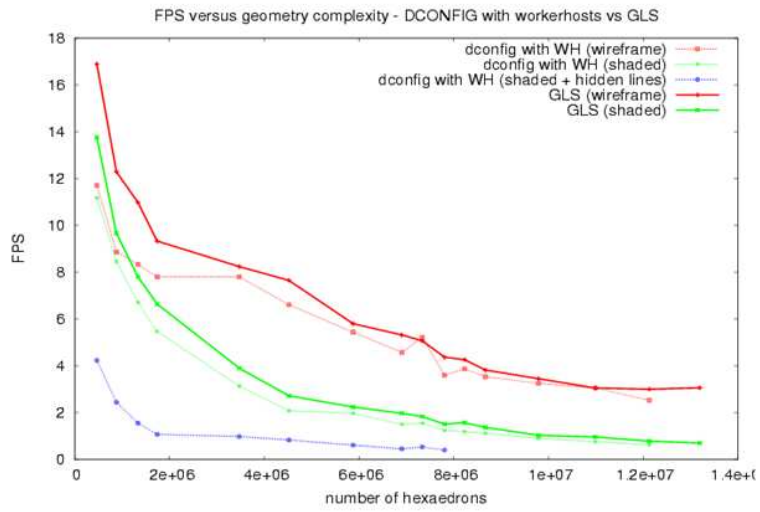


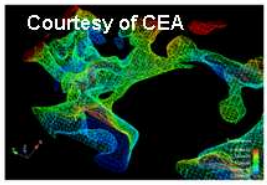

# libGLs

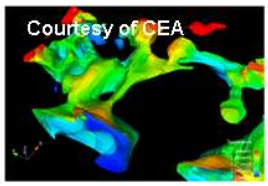
*Comparison with Chromium (bench: glbench)*

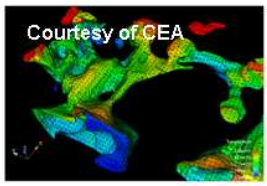



## *Comparison with DCONFIG 2x4 (EnSight + meteor)*



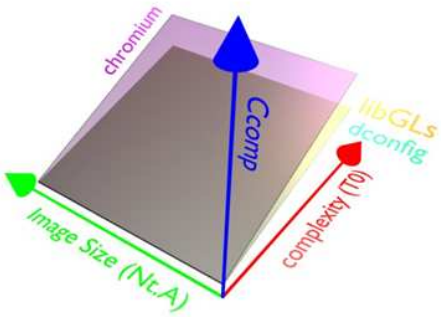

*RAM :*

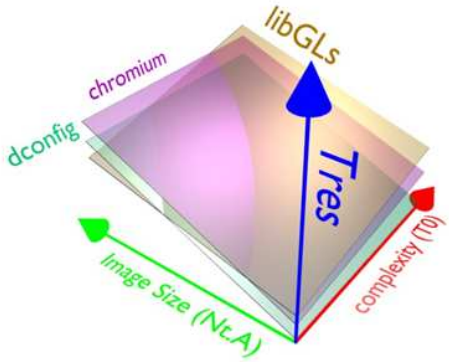
*DCONFIG : 38 Go*

*libGLs : 21 Go*

libGLs

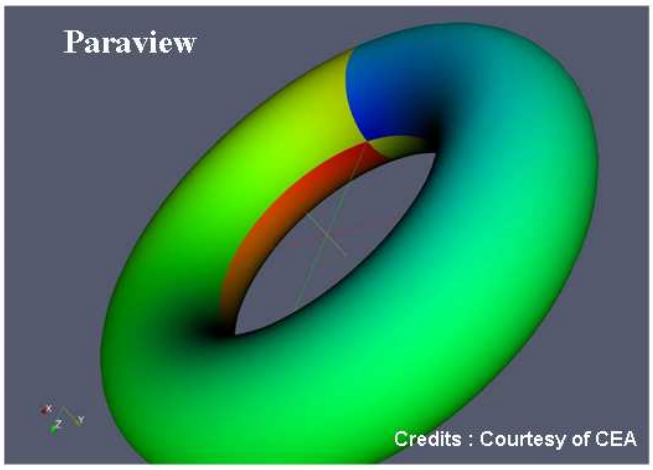
## Theoretical comparison with *DCONFIG and Chromium :*



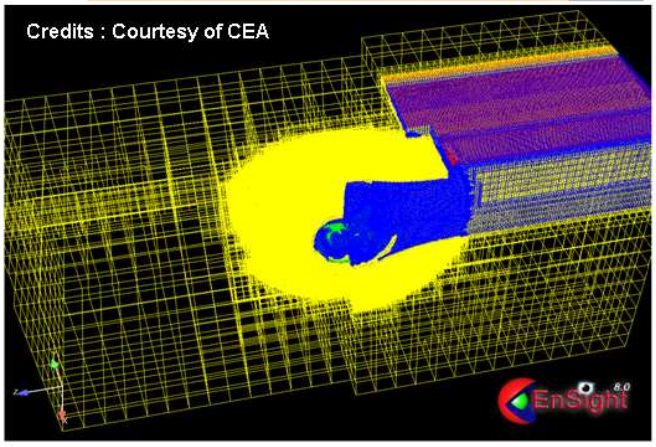




| | dconfig | libGLs | Chromium |
|---|---|---|---|
| Réseau | $O(N_T N_{wh} A)$ | $O(T_0 N_T r_c + N_T N_{wh} A r_i)$ | $O(T_0 + N_T N_{wh} A)$ |
| Calcul/rendu | $O(\frac{T_0}{N_{wh}} + log_2(N_{wh})A)$ | $O(\frac{T_0}{N_{wh}})$ ou $O(\frac{T_0}{N_{wh}} + log_2(N_{wh})A)$ | $O(\frac{T_0 N_T}{N_{wh}})$ ou $O(\frac{T_0}{N_{wh} N_T} + log_2(N_{wh})A)$ |
| Mémoire | $O(T_0)$ | $O(T_0)$ ou $O(1)$ | $O(T_0)$ ou $O(1)$ |

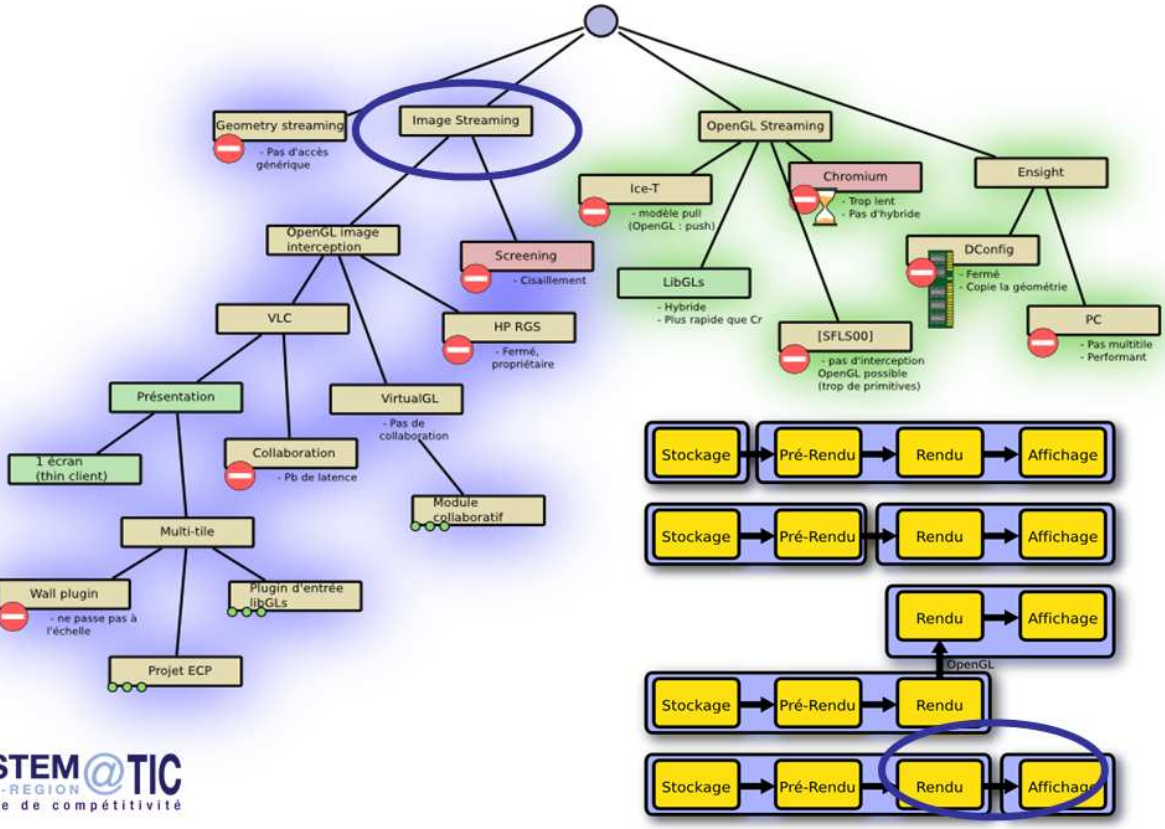
# libGLs : transparent, generic





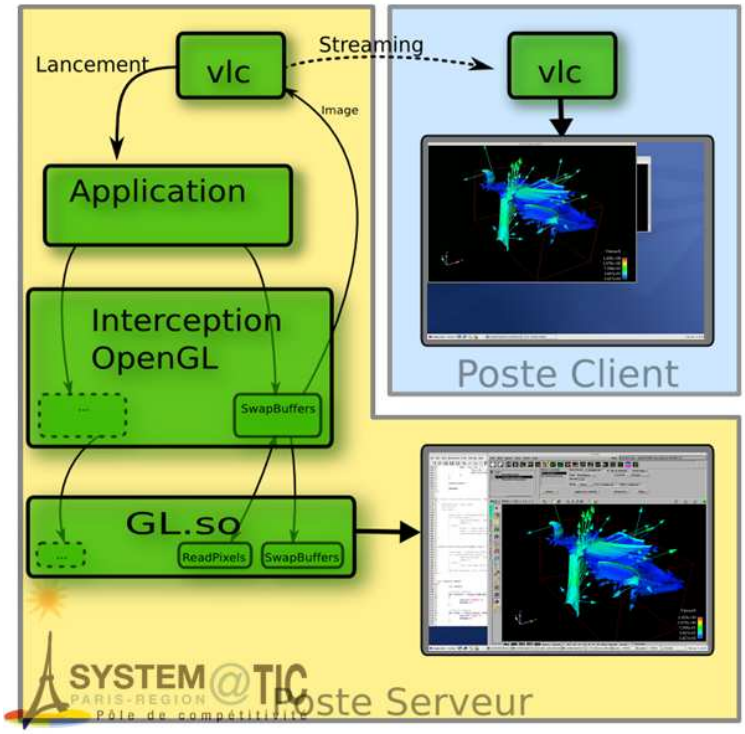



# CEA experiments...



# Remote visualization (CEA, ECP)

- Trying VLC as a remote display engine



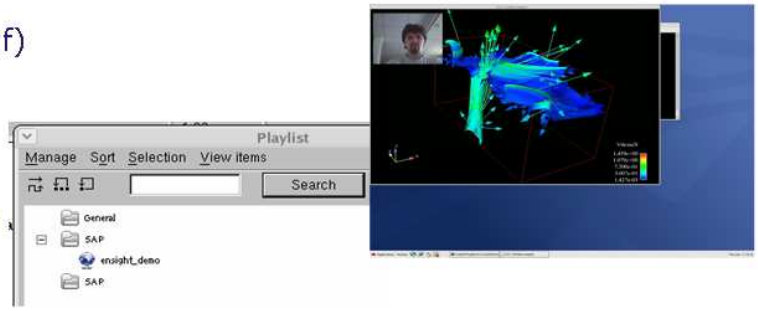

- Server side :
  - Une version modifiée de VLC
  - Interception lib
  - app (ex: EnSight)
  - OpenGL
- Client side :
  - Multimedia reader (e.g. VLC)

VLC steams the framebuffer contents via the network



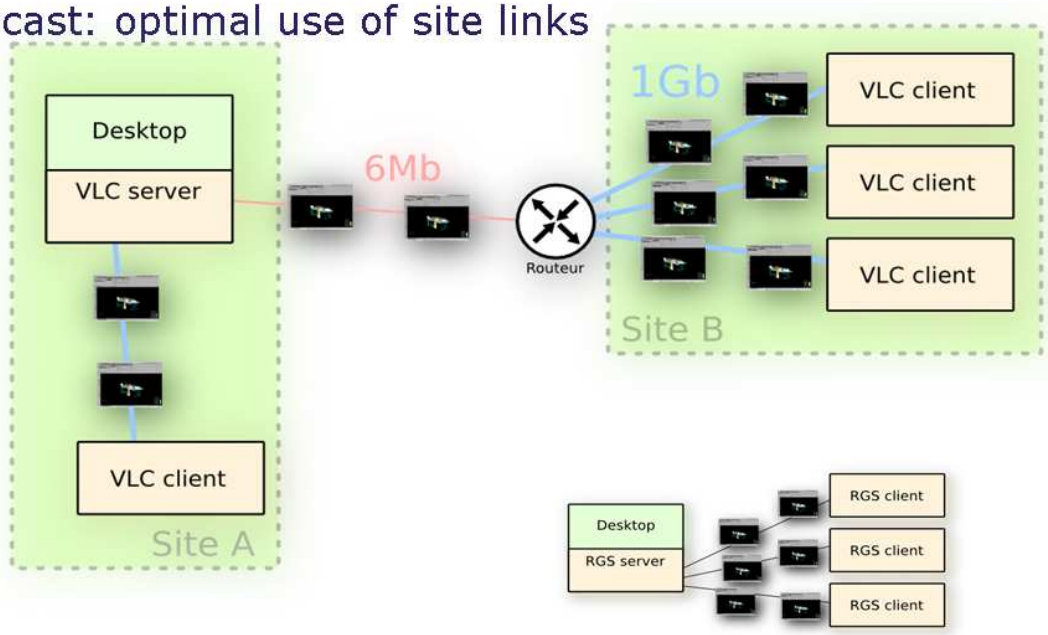
# Results - VLC

- Advantages
  - Transparent (application unchanged), generic
  - Client side: multimedia reader only
  - Video codec ( ≠ HP2: image codec ): interframe redundancy
  - Video rate and quality tuning (choice of codec and/or bitrate)
  - Other streams can be added:
    - Sound
    - Webcam (visio-conf)
    - Subtitles
  - GPL license
  - Modular
  - Low CPU workload
  - Multicast



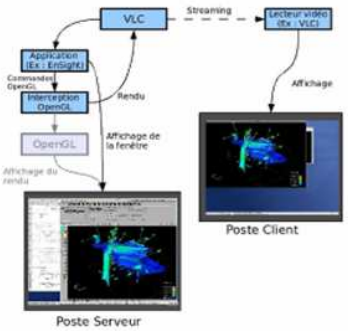
## Results - VLC

- Multicast: optimal use of site links




## VLC

- Limitations
  - Most of workload on server ( application+compression)
    No distribution flexibility
  - MP4V: lower quality than HP2 (RGS)
  - Latency (~1s)
- Collaboration can be handled
  - Add modules on server and client sides
- Web service can be handled
  - VLC plugin for web portal
  - Java applet for collaboration
- ECP is possibly going to further study:
  - the latency issue (profiling in a MT mode…)
  - the parallel streaming possibilities (several rendering streams in case of parallel rendering)
  - other encoders ?



# Part 3 : Future work

NextGen VLC

VISUPORTAL HD

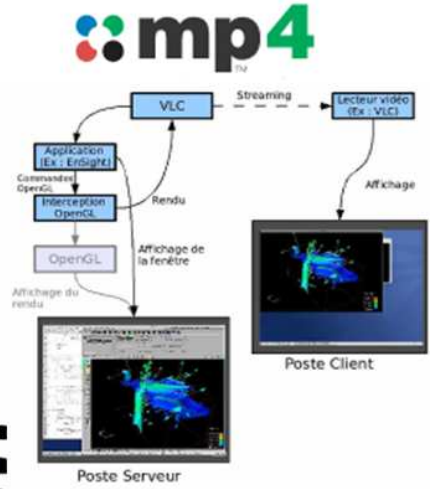
2009 : « virtualisation » of the CARRIOCAS R&D technologies

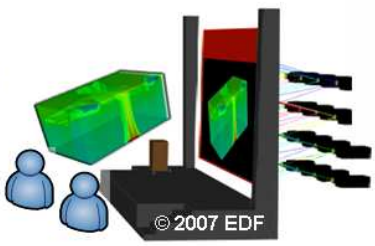


## R&D : « NextGen »VLC

Contributors : ECP with CEA and OXALYA

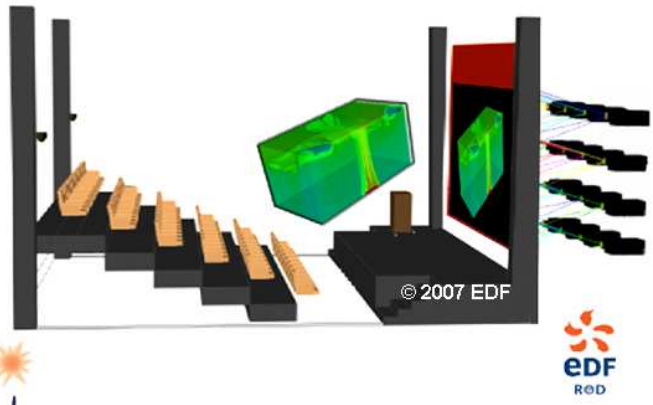
- New conception/architecture
  - Optimisation of « streaming video»
  - Realtime MPEG 4 encoding
  - Parallel streams ?
- Collaborative mode
- Easy deploiement plugin
- Support for every display :
  - HR display
  - Classic display



## VISUPORTAL HD for High Resolution Display

- R&D « VISUPORTAL HD » at EDF and CEA with OXALYA
  - On Compute & Graphic clusters to manage
    - MIRAGE Jr (CEA-TER@TEC experimental HR display)
    - EDF HR display which will be installed 1st semester 2008 in Clamart (92).
  - Supporting EnSight Gold, DR and other very valuable opensource software packages

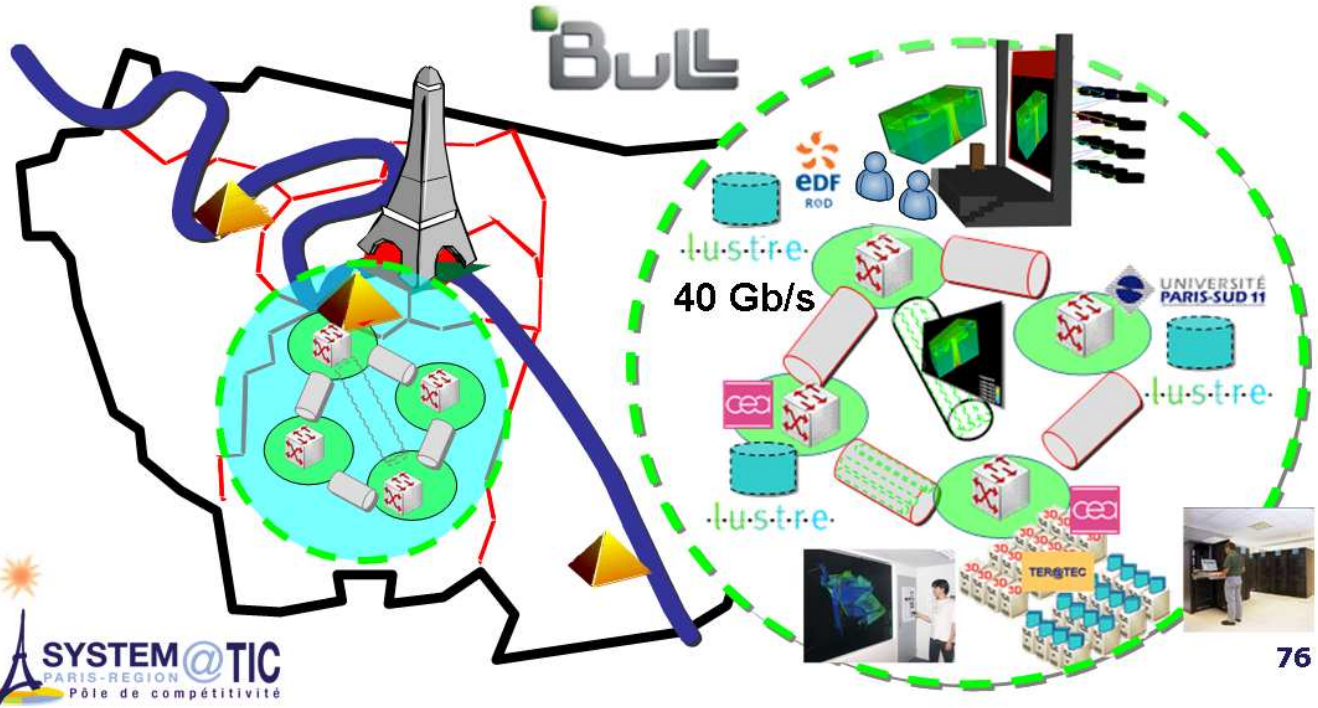






## Final installation of the remote technical infrastructures for the final demo!

- **2009** : Time to « Virtualize » all the validated and implemented technologies with BULL



# Conclusion

- This Visuportal experiment is definitely a tremendous result for the CARRIOCAS team
- **So thank you again to all the colleagues : EDF and partners CEA, ECP, OXALYA!**

- EDF is leading, with the CEA, the R&D in the CARRIOCAS project of the future of using high performance visualization ressources. EDF shares this view with other industrials and Academics.

- **Don't hesitate to contact us !**

- **The partners will be pleased to have your comments and questions**

**Contacts :**
**CEA :** Dominique RODRIGUES, Jean-Philippe NOMINE
**ECP** : Christian SAGUEZ, Céline HUDELOT
**EDF :** Jean-Yves BERTHOU, Christophe MOUTON
**OXALYA :** Alban SCHMUTZ, Thibaut LAURENT



CARRIOCAS

- Voir aussi www.carriocas.org