HPC on Cloud for SMEs. The case of bolt tightening.

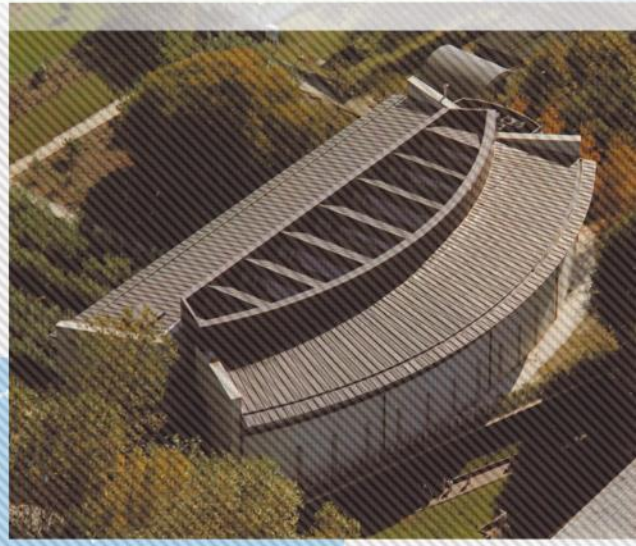
A. Gómez, C. Cotelo (CESGA)

G. Rodríguez (Texas Controls), J. Souto (AIMEN)

18/06/2015

ESTABLISHED IN 1993 IN SANTIAGO DE COMPOSTELA (SPAIN)

CESGA



CESGA

Mission Statement

To provide high performance computing and advanced communications resources and services to the scientific community of Galicia and to the Spanish National Research Council (CSIC), as well as, to institutions **and enterprises with R&D&I activity**.

To promote high quality research in Computational Science in close collaboration with the research community from Galicia as well as from other regions or countries all over the world; contributing in this way to the advancement of science, **to transfer technology to industry and administrations**, and as consequence, to the welfare of society as a whole.

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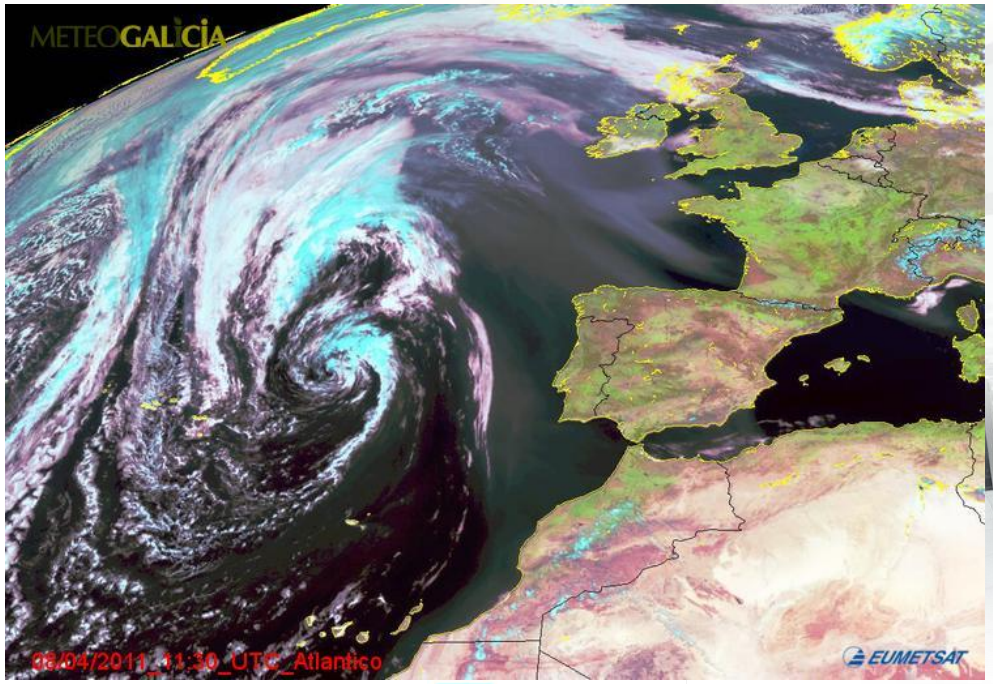
Examples of services

Simulations for the Regional Weather Office

meteogalicia



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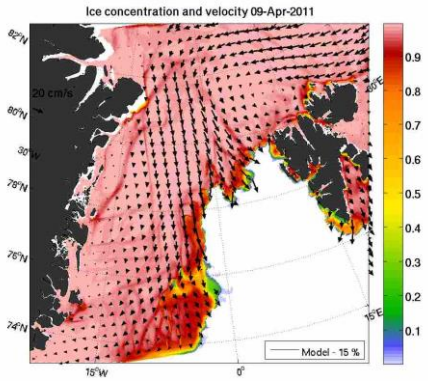
Examples of use

European IBI Area: Ocean Forecasting Service



Puertos del Estado

Spanish Port Authority

Enrique Alvarez Fanjul

meteogalicia

myOcean

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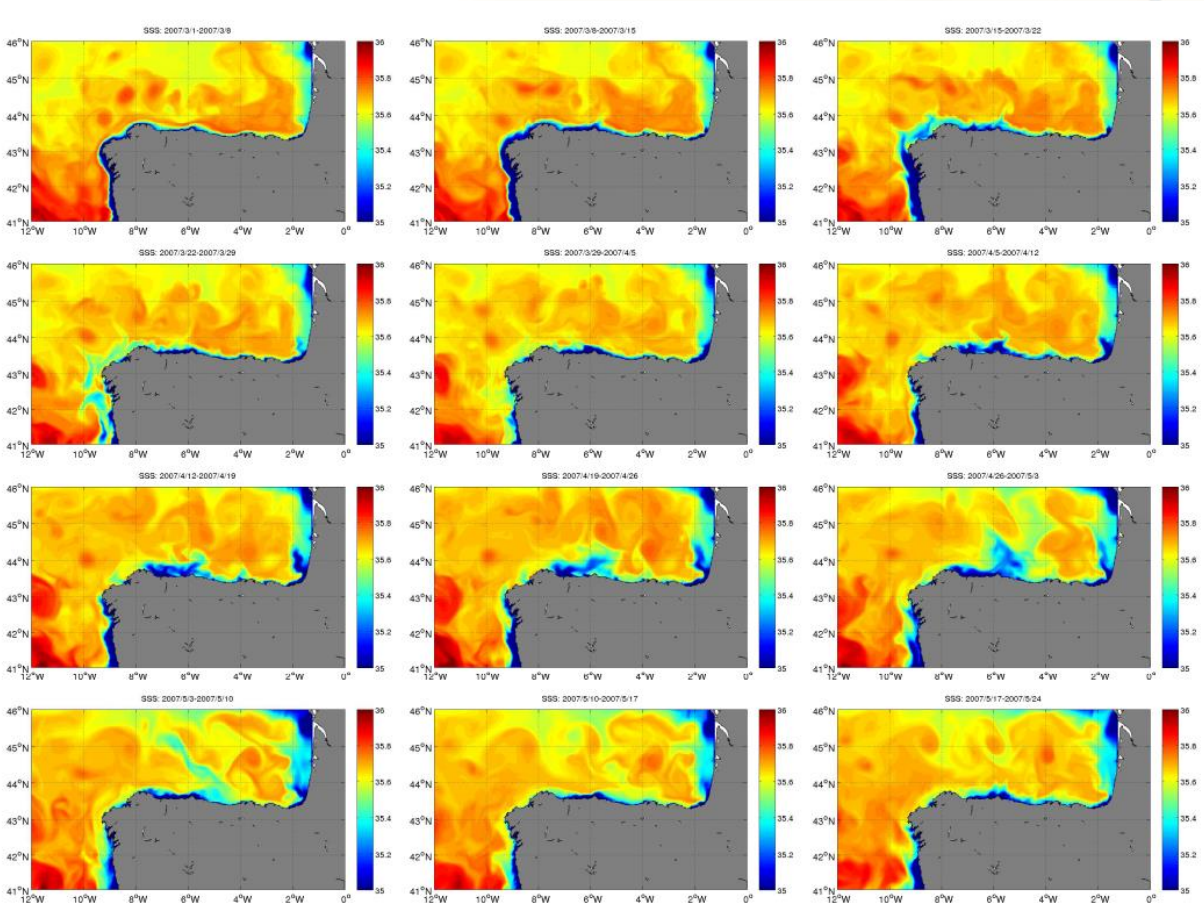
Examples of use

Oceanographic simulation to better understand fisheries population dynamics



INSTITUTO ESPAÑOL DE OCEANOGRAFÍA 1914

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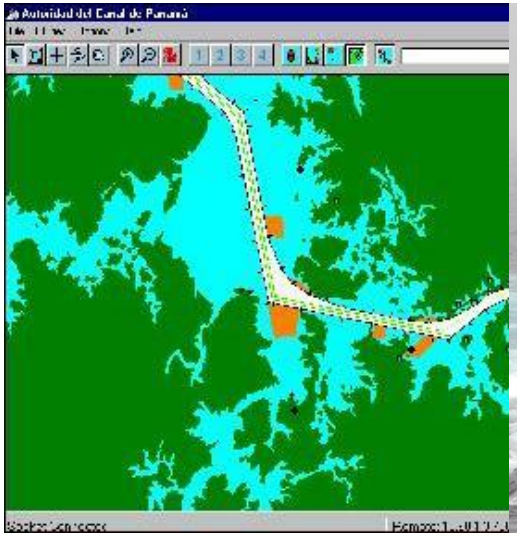
Colaborative Research with universities

Large scale electromagnetism simulation for improved radar systems



Universidade Vigo

UEX Universidad de Extremadura

billion one
electromagnetics world record / by hemcuve

UVIGO – UNEX – CESGA

Fernando Obelleiro Basteiro

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HPC for SMEs

*"… HIGHLIGHTS that HPC is a crucial asset for the EU's innovation capacity and STRESSES its **strategic importance** to benefit the EU's industrial capabilities as well as its citizens, by innovating industrial products and services, increasing competitiveness, and addressing grand societal and scientific challenges more effectively."*

*Draft Council Conclusions on **'High Performance Computing: Europe's place in a Global Race**'" of March 27th, 2013*

But for SMEs, HPC does not always mean big supercomputers

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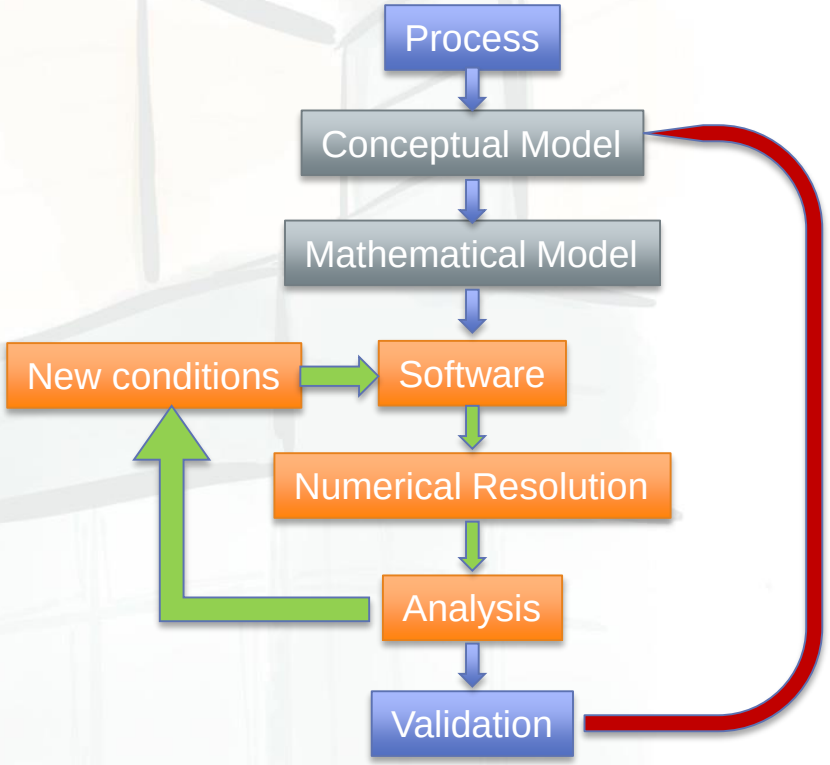
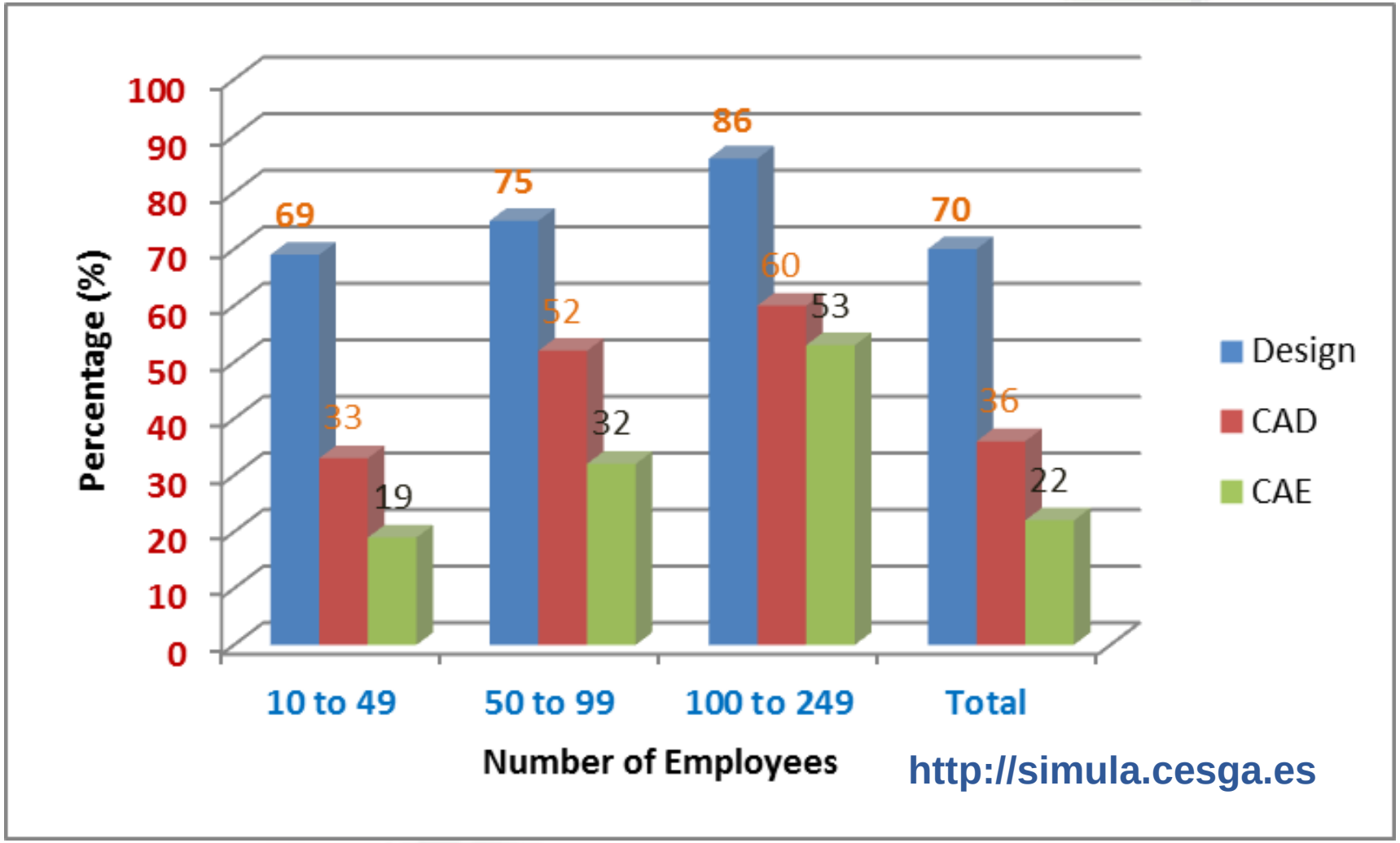
What is HPC?

High Performance Computing (HPC) is the use of servers, clusters, and supercomputers – plus associated software, tools, components, storage, and services – for scientific, engineering, or analytical tasks that are particularly intensive in computation, memory usage, or data management

Intersec360



SIMULATION IN SMEs in Galicia (2004)



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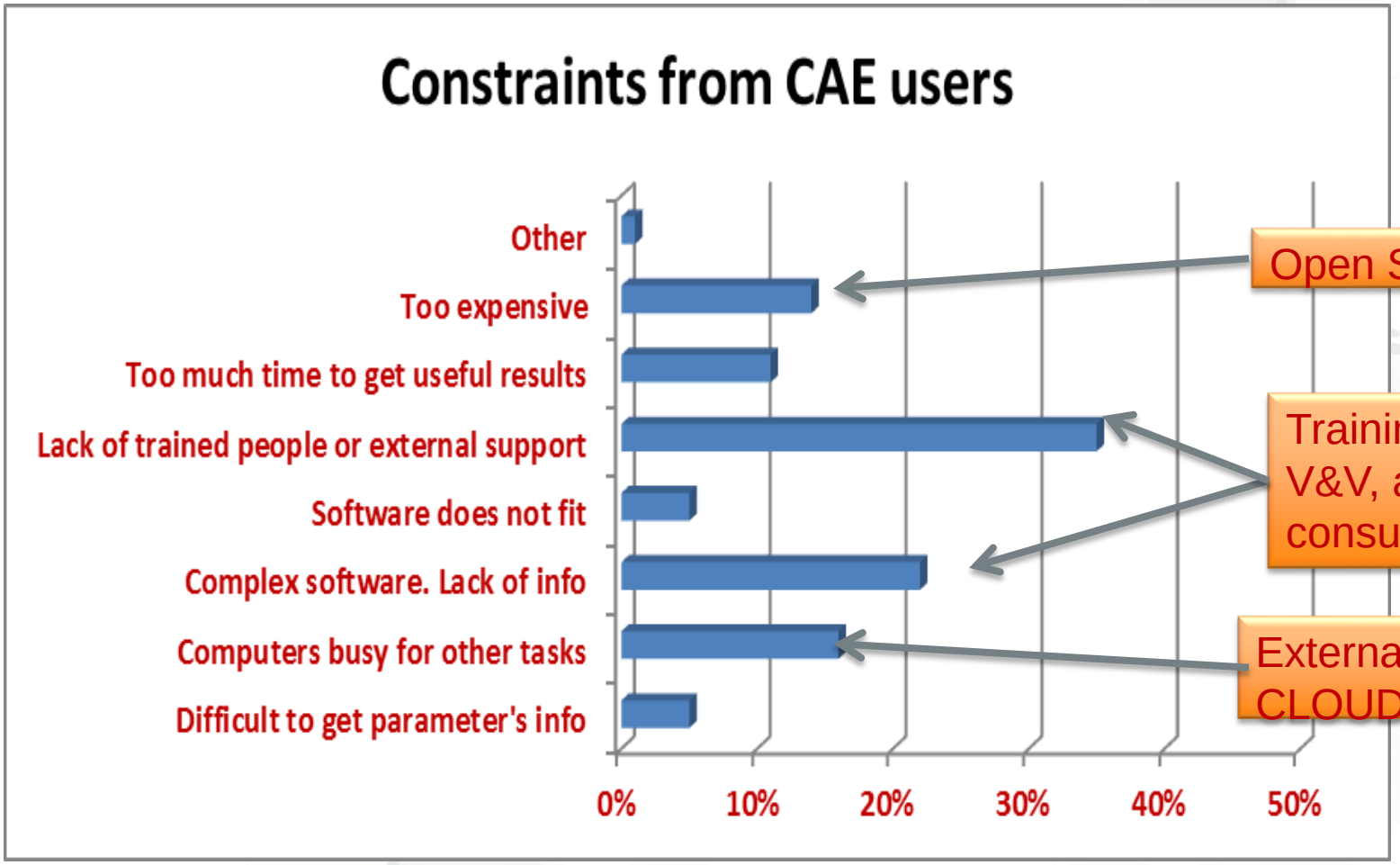
Constraints



http://simula.cesga.es

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Initial solution: Cloud services in ne

CloudPYME

CESGA

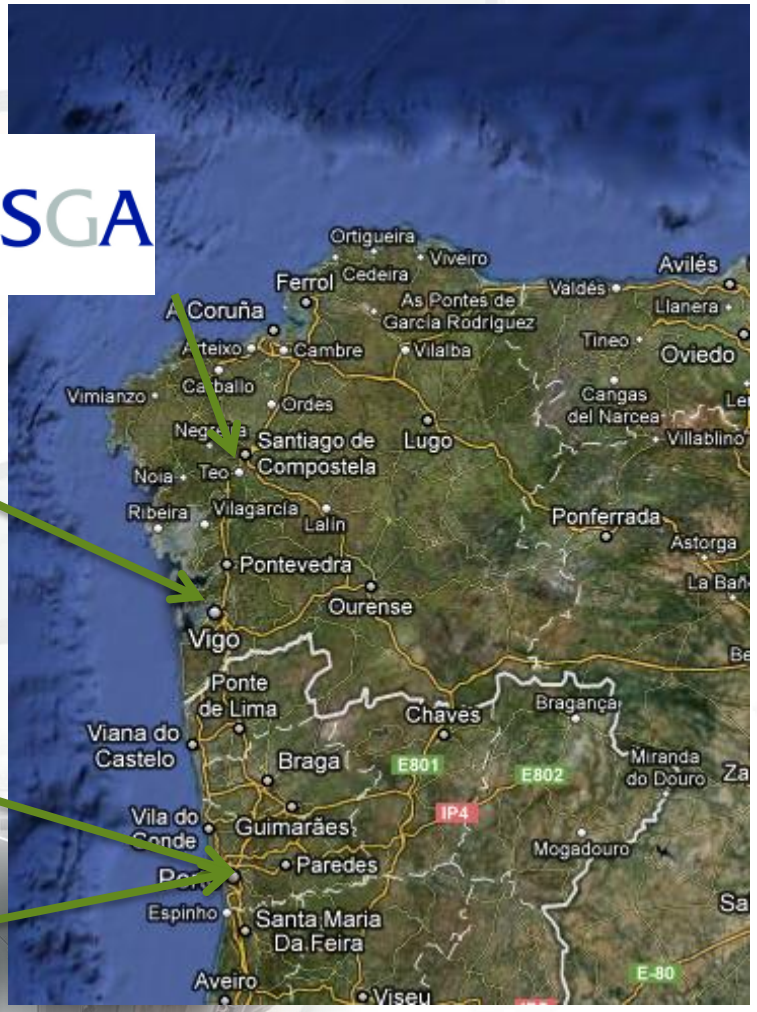
http://www.cloudpyme.eu

aimen
CENTRO TECNOLÓGICO

Centros Tecnológicos

AIMMAP
ASSOCIAÇÃO DOS INDUSTRIAIS METALÚRGICOS, METALOMECÂNICOS E AFINS DE PORTUGAL

CATIM



PROGRAMA COOPERACIÓN TRANSFRONTERIZA ESPAÑA – PORTUGAL COOPERAÇÃO TRANSFRONTEIRIÇA 2007 – 2013

0682_CLOUDPYME2_1_E

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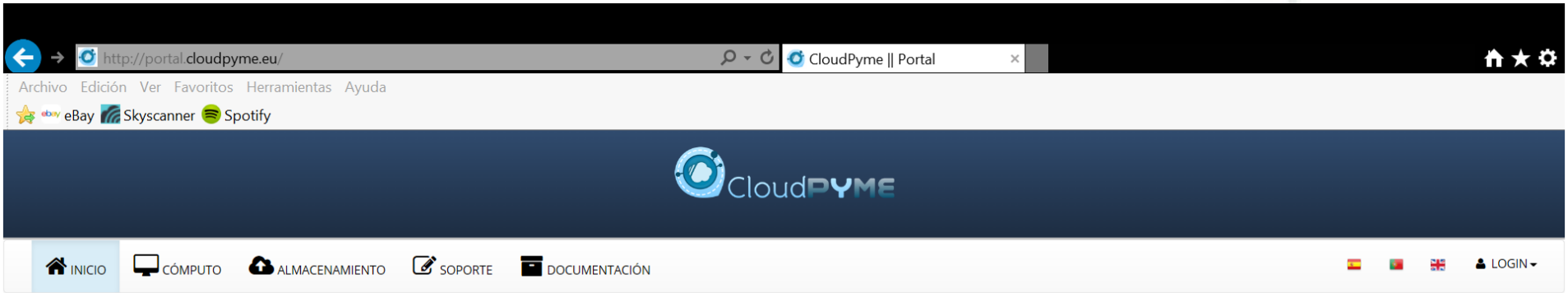
Invertimos en su futuro

CESGA



PROGRAMA COOPERACIÓN TRANSFRONTERIZA ESPAÑA - PORTUGAL COOPERAÇÃO TRANSFRONTEIRIÇA

aimen CENTRO TECNOLÓGICO

AIMMAP ASSOCIAÇÃO DOS INDUSTRIAIS METALÚRGICOS, METALOMECÂNICOS E AFINS DE PORTUGAL

catim

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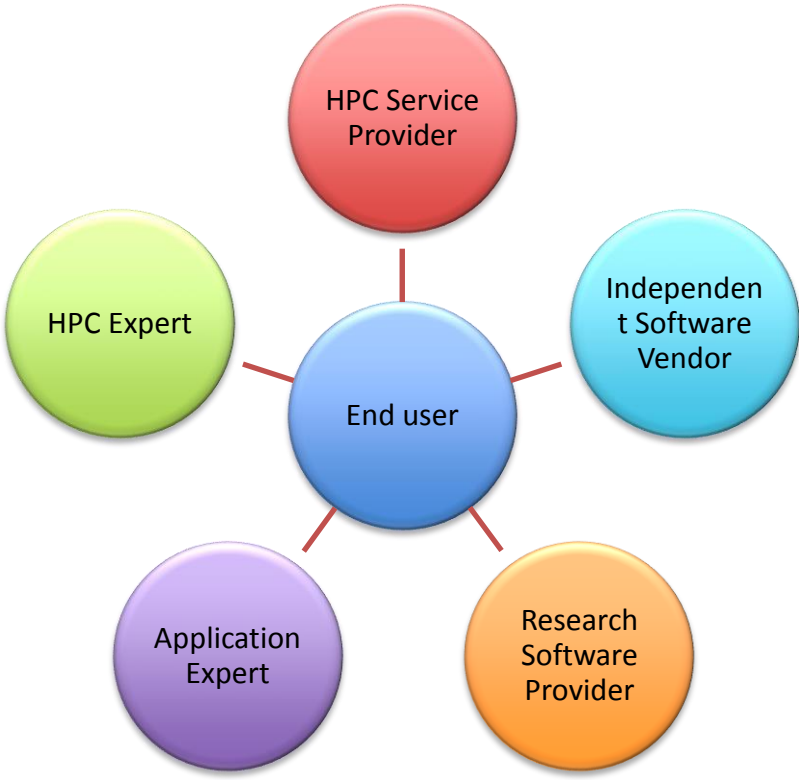
What do they need?

- Help with M&S and validation
- Vertical Applications/Easy interfaces
- Confidentiality
- Remote storage/HPC/Visualization
- Time-to-solution



FORTISSIMO has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 609029

FF404: Case of study

Why M&S Tightening?

- TEXAS Controls **core business**.
- There is **no software solution in the market.**
- It seems **feasible to do** it **with open source** software.
- The SME **does not have** the required **computer capacity**.
- A **challenge** regarding modelling, **simulation**, and execution.

FORTISSIMO has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 609029

End User/Company Profile:

Headquarters
LA CORUÑA

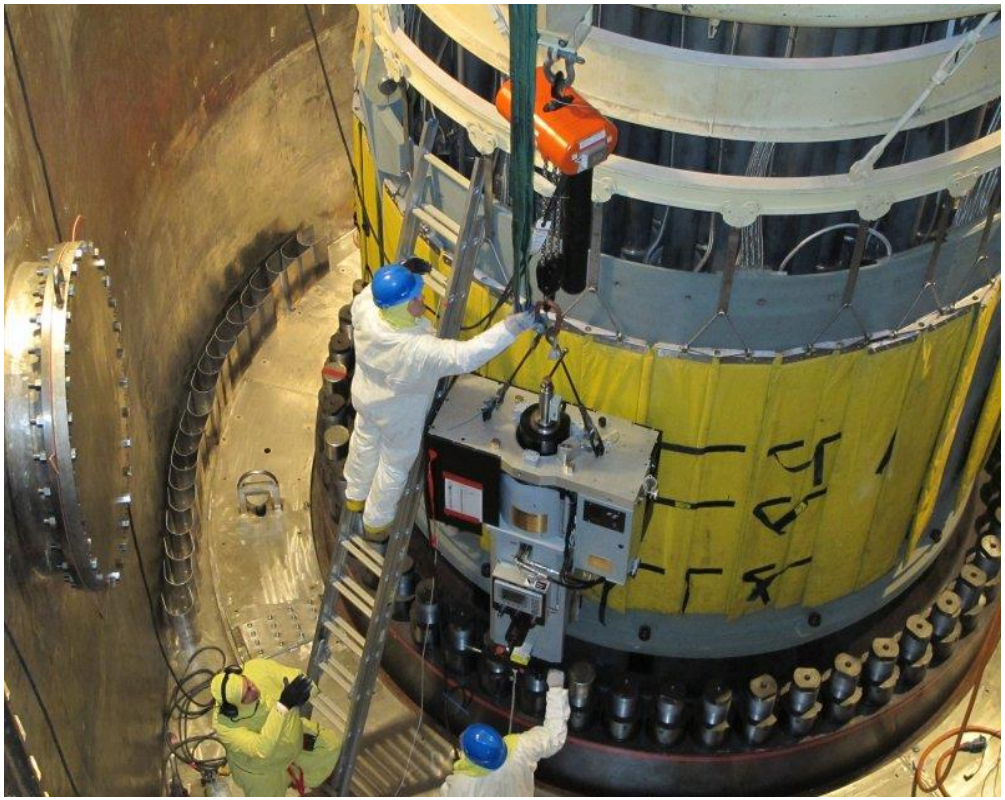
BRASIL
(NATAL-RÍO GRANDE
DO NORTE)

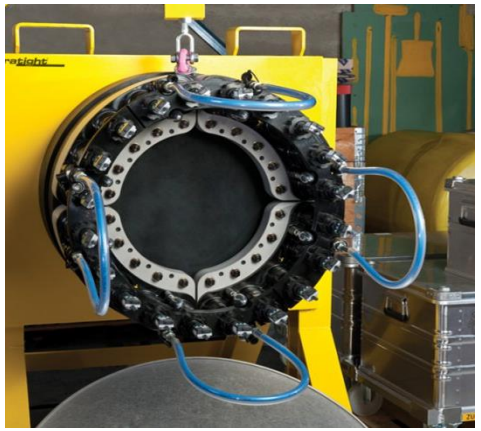
TARRAGONA

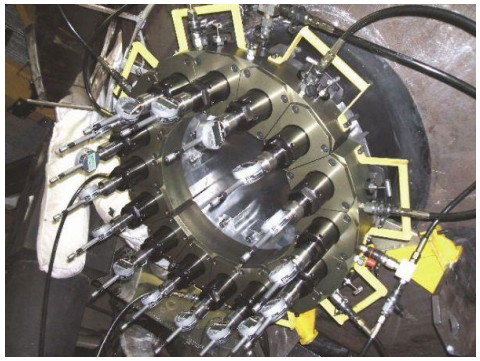
MADRID

Tightening examples

Nuclear plants

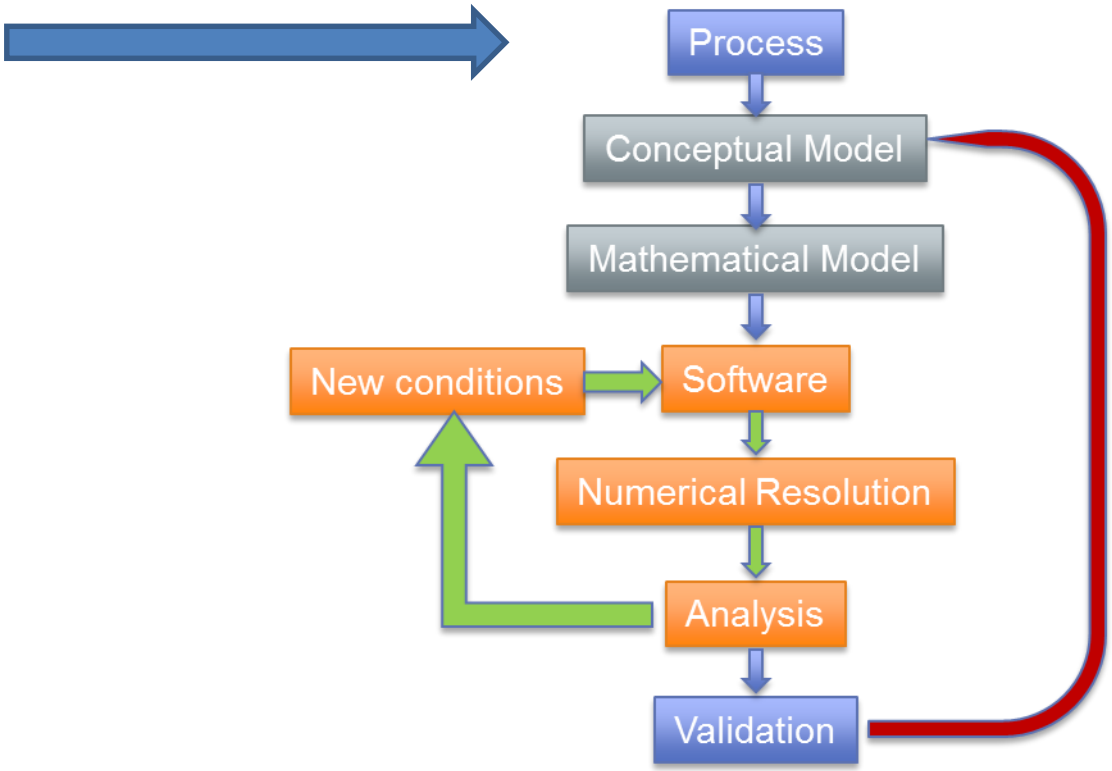






Try to Reduce operational time & the time exposure to radiation.

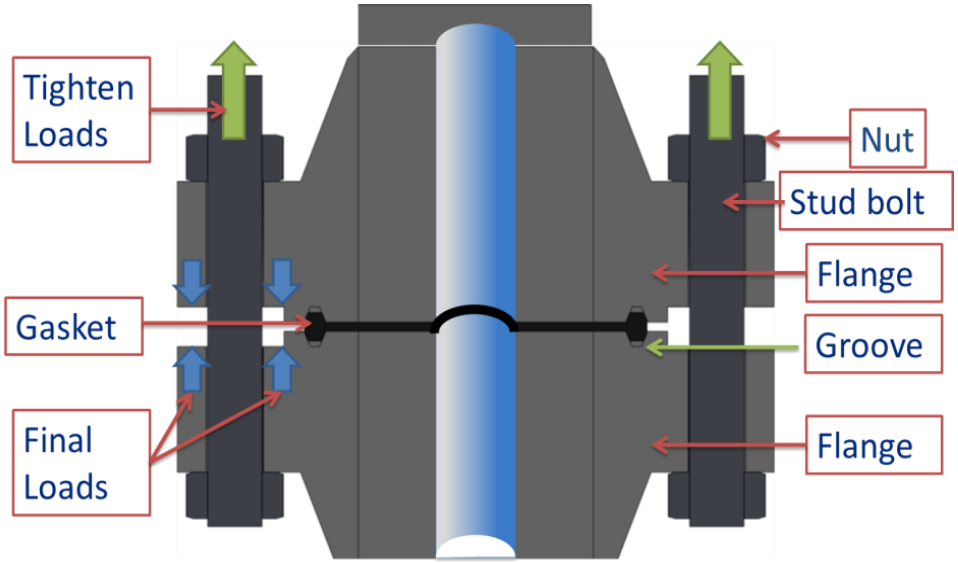
The process
(Il processo)

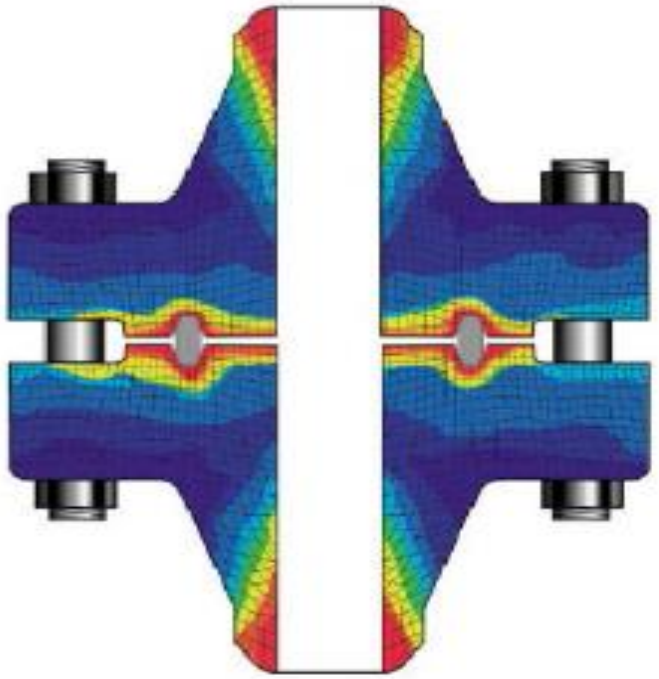


Tightening process

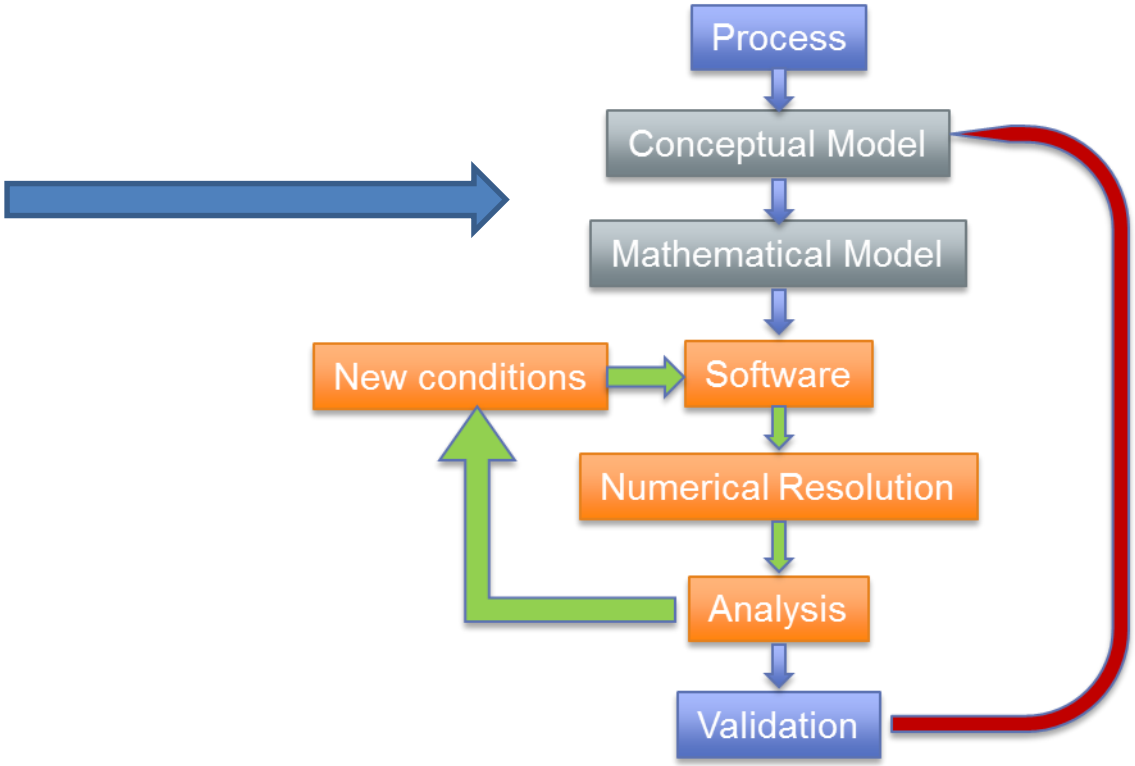
Study and prediction of flanges behavior during tightening process.

What is the best strategy to execute it?



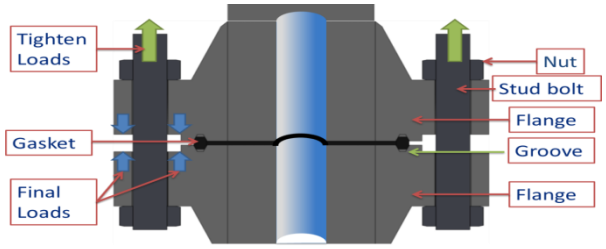


The Model
(Il modello)



The model

Contact-Friction model

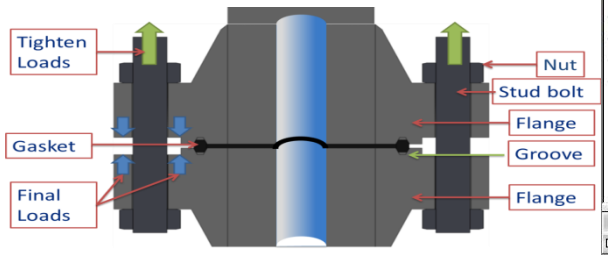


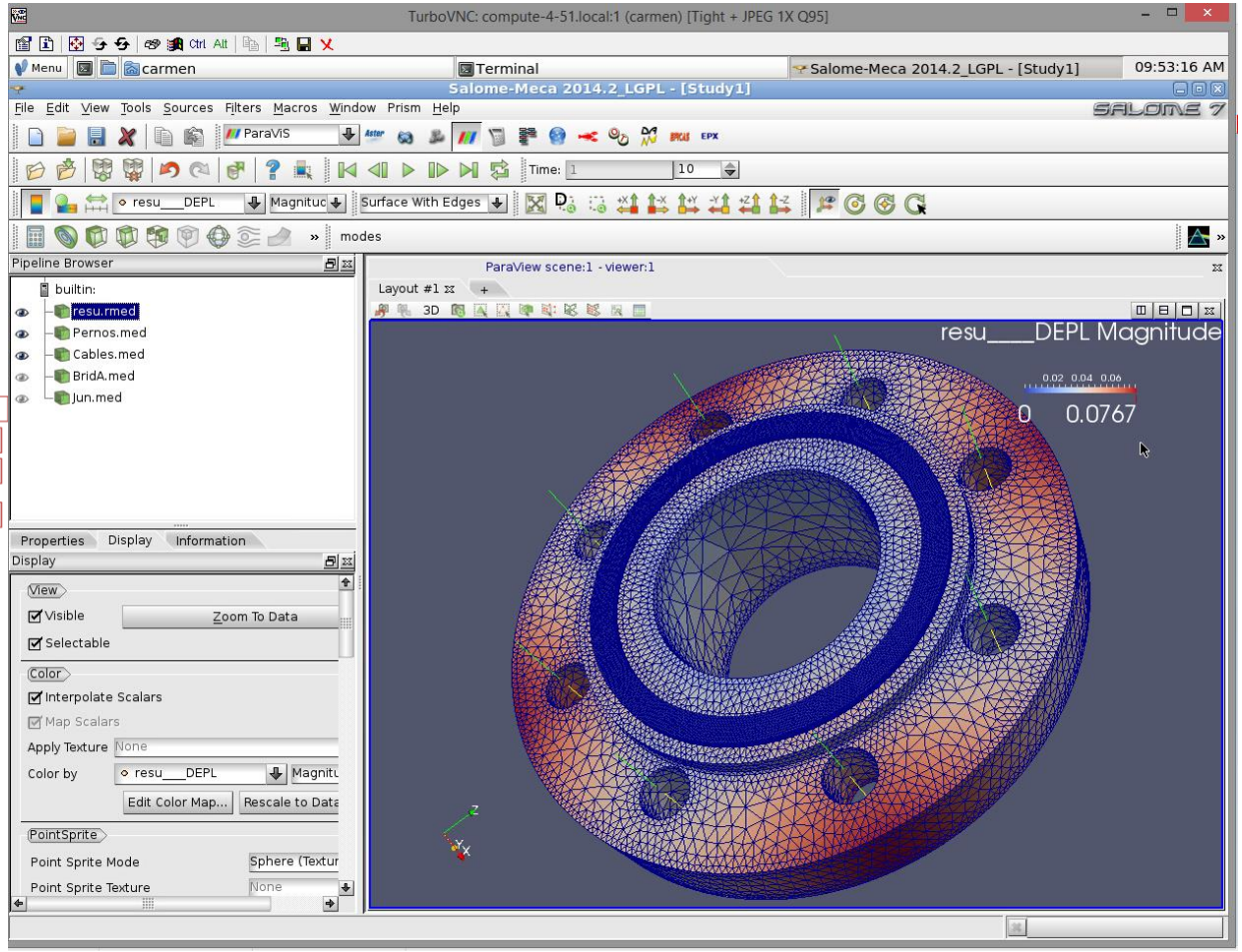
Materials	Design	Sequence parameters
• Flanges • Gasket • Bolts	• Nr bolts • Groove • Flange • Bolts • Gasket	• Initial load • Residual load • Steps of tightening • Groups of tightening

Parametric simulations: huge number of cases to obtain the optimal design

The model

Contact-Friction model





Taguchi method

The Taguchi method is a standardized approach for determining the best combination of inputs to produce a product or service.

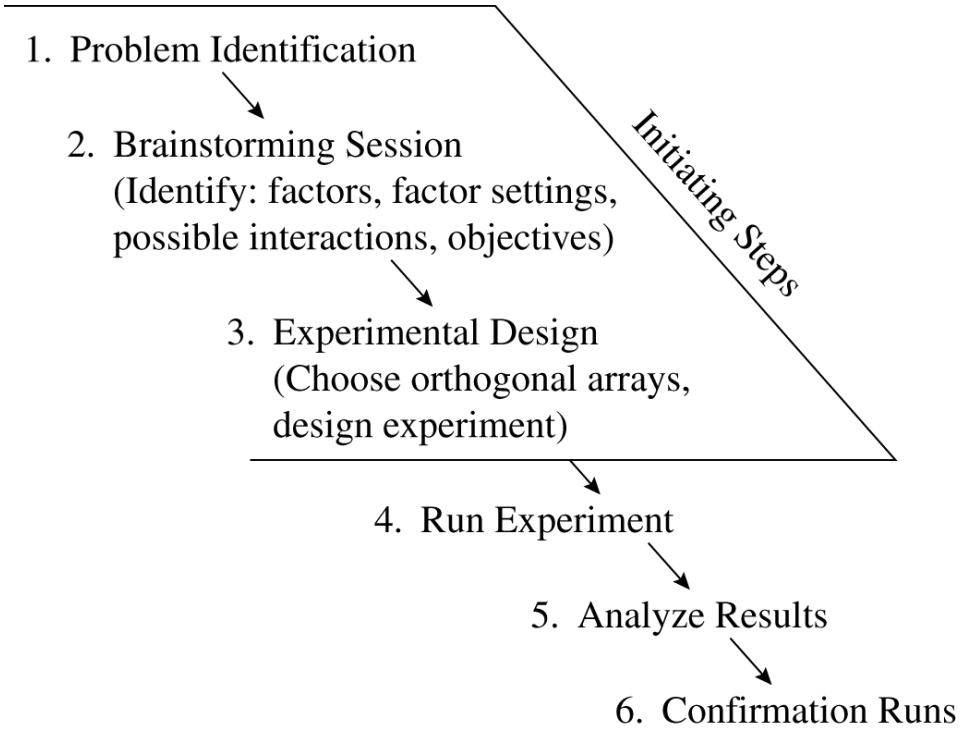


Image source: Chapter 7S ©2001 Slides Prepared by Bruce R. Barringer University of Central Florida S. Thomas

Parametric jobs: Taguchi

TAGUCHI METHOD:

The approach for this experiment corresponds to the Taguchi L'16 orthogonal array (up to 4 levels & 5 parameters), i.e. up to 16 parametric jobs . The runtimes for each of these parametric jobs are very similar.

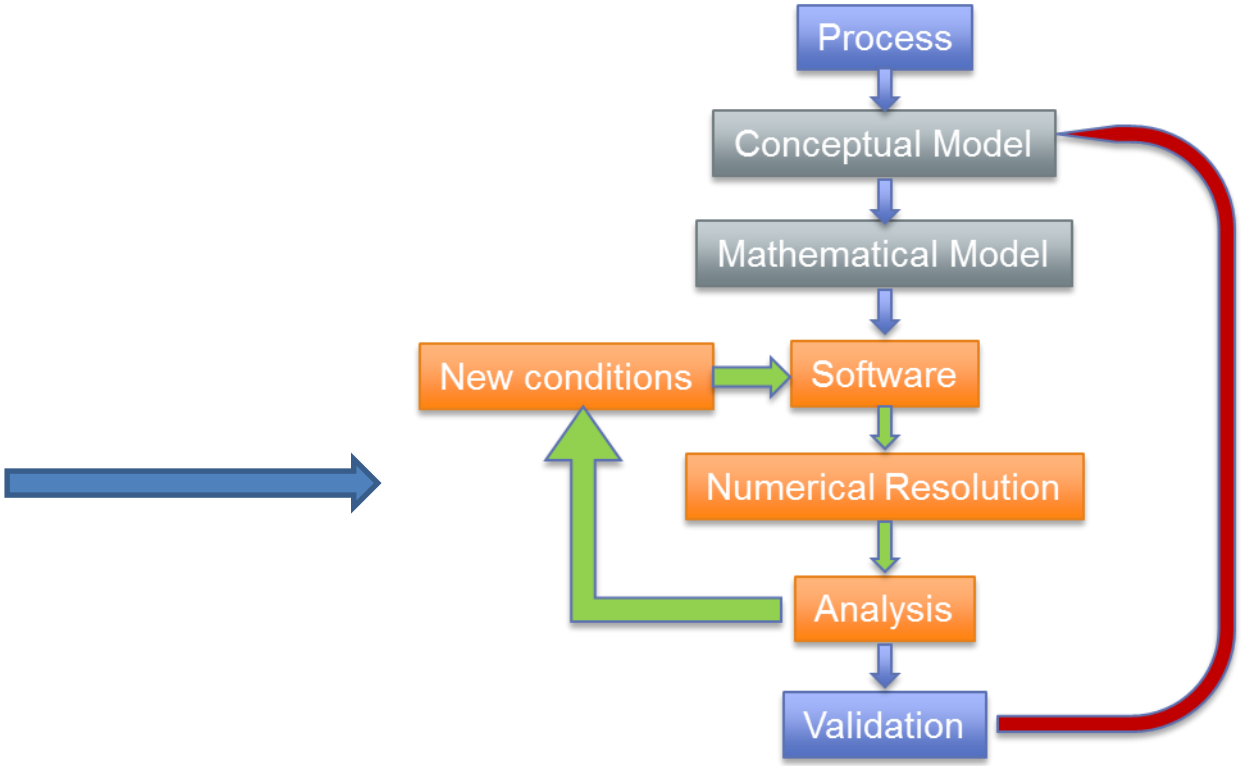
PARAMETERS:

- Materials for flanges and gaskets
- Number of bolts for each subset (strategy);
- Final load value (minimum load) .
- Maximum load for each step.

Taguchi L'16 orthogonal array

Experiment	P1	P2	P3	P4	P5
1	1	1	1	1	1
2	1	2	2	2	2
3	1	3	3	3	3
4	1	4	4	4	4
5	2	1	2	3	4
6	2	2	1	4	3
7	2	3	4	1	2
8	2	4	3	2	1
9	3	1	3	4	2
10	3	2	4	3	1
11	3	3	1	2	4
12	3	4	2	1	3
13	4	1	4	2	3
14	4	2	3	1	4
15	4	3	2	4	1
16	4	4	1	3	2

The software
(Il software)



Contact-friction model

- **Code_aster** (and Abaqus for initial model verification)
- Taguchi implementation:
  - Python script which receives the number of parameters/levels from the web application and generates the different number of .comm files (input) for the parametric jobs.
  - Embedded python in the Code_Aster .comm file for controlling the tightening workflow .
  - Job arrays : same job using different .comm file.
- Symmetries, Choices of surfaces main and slaves and Quality of the mesh
- Numerical Resolution:
  - Discrete formulation: ALGO_CONT , ALGO_FRO. Options: LAGRANGIAN or GCP algorithm
  - Formulation continue: ALGO_RESO_CONT, ALGO_RESO_FROT, ALGO_RESO_GEOM. Options: POINT_FIX or NEWTON algorithm.
- Solvers: MULT_FRONT, MUMPS, LDLT, PCG, PETSC or FETI
- In case of MPI solvers: PARALLELISME = CENTRALISE, GROUP_ELEM, MAIL_DISPERSE, MAIL_CONTIGU, SOUS_DOMAINE

Contact-friction model

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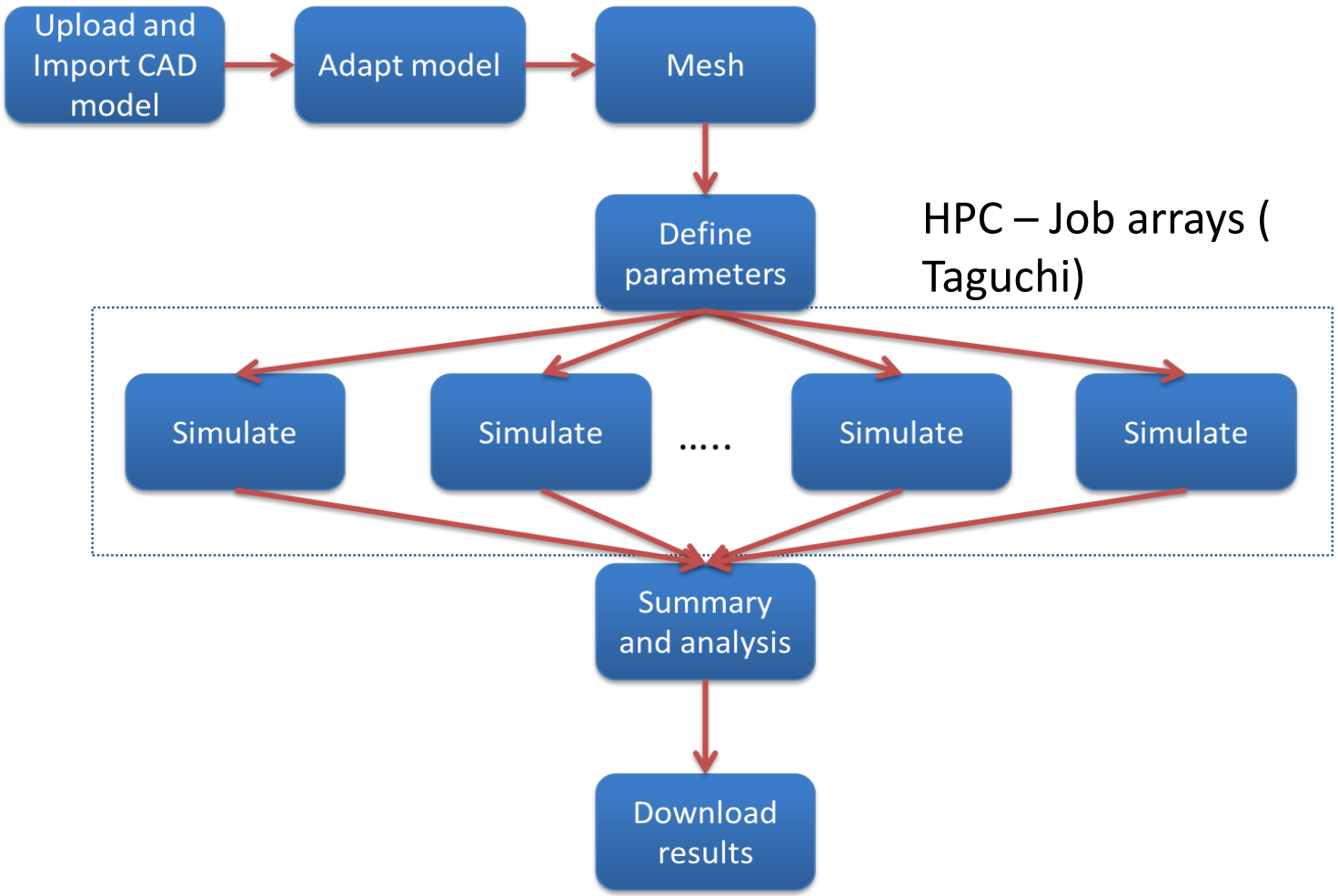
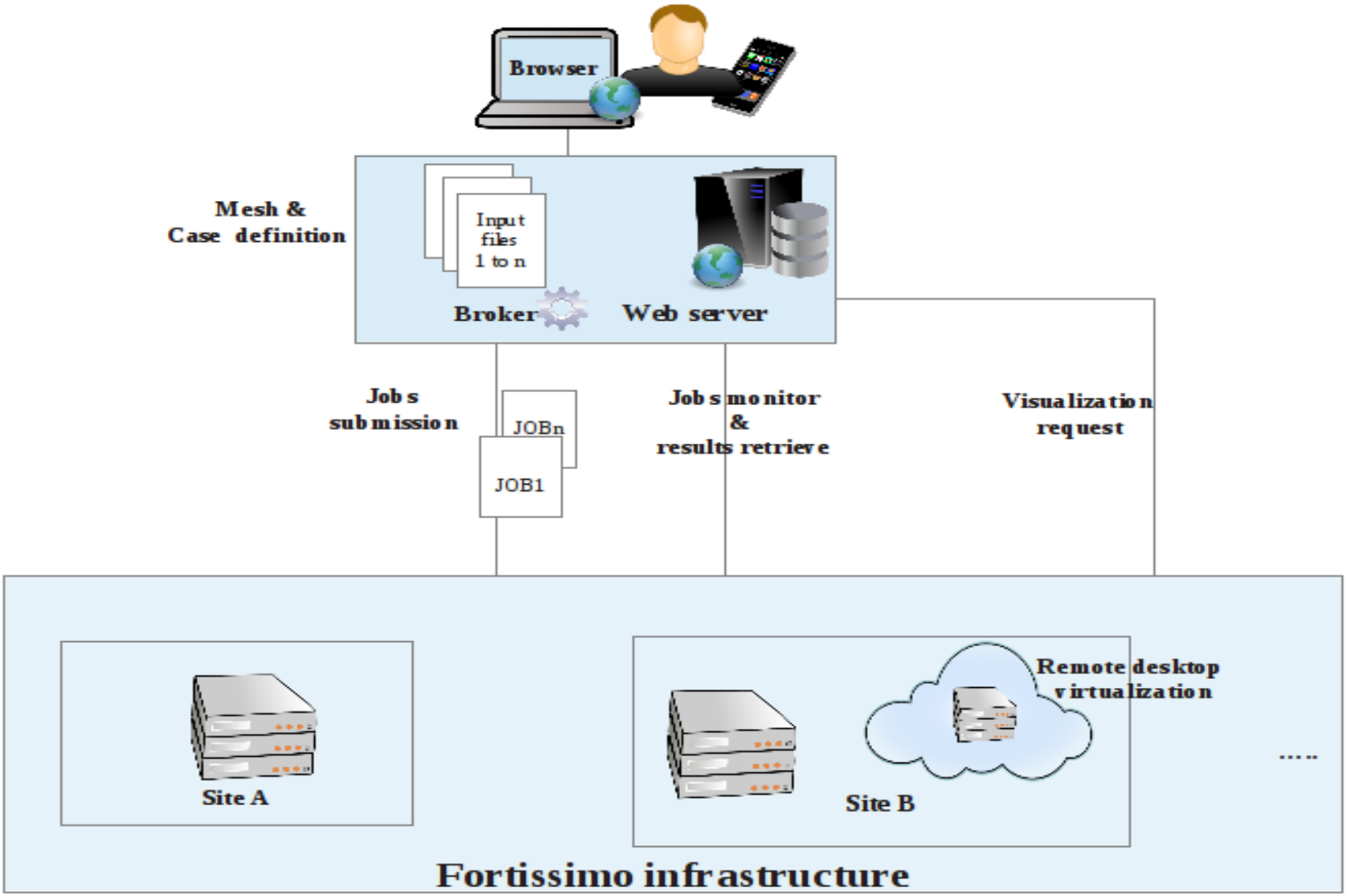
- In case of MPI solvers: PARALLELISME = CENTRALISE, GROUP_ELEM, MAIL_DISPERSE, MAIL_CONTIGU, SOUS_DOMAINE

Too complicated for most SMEs

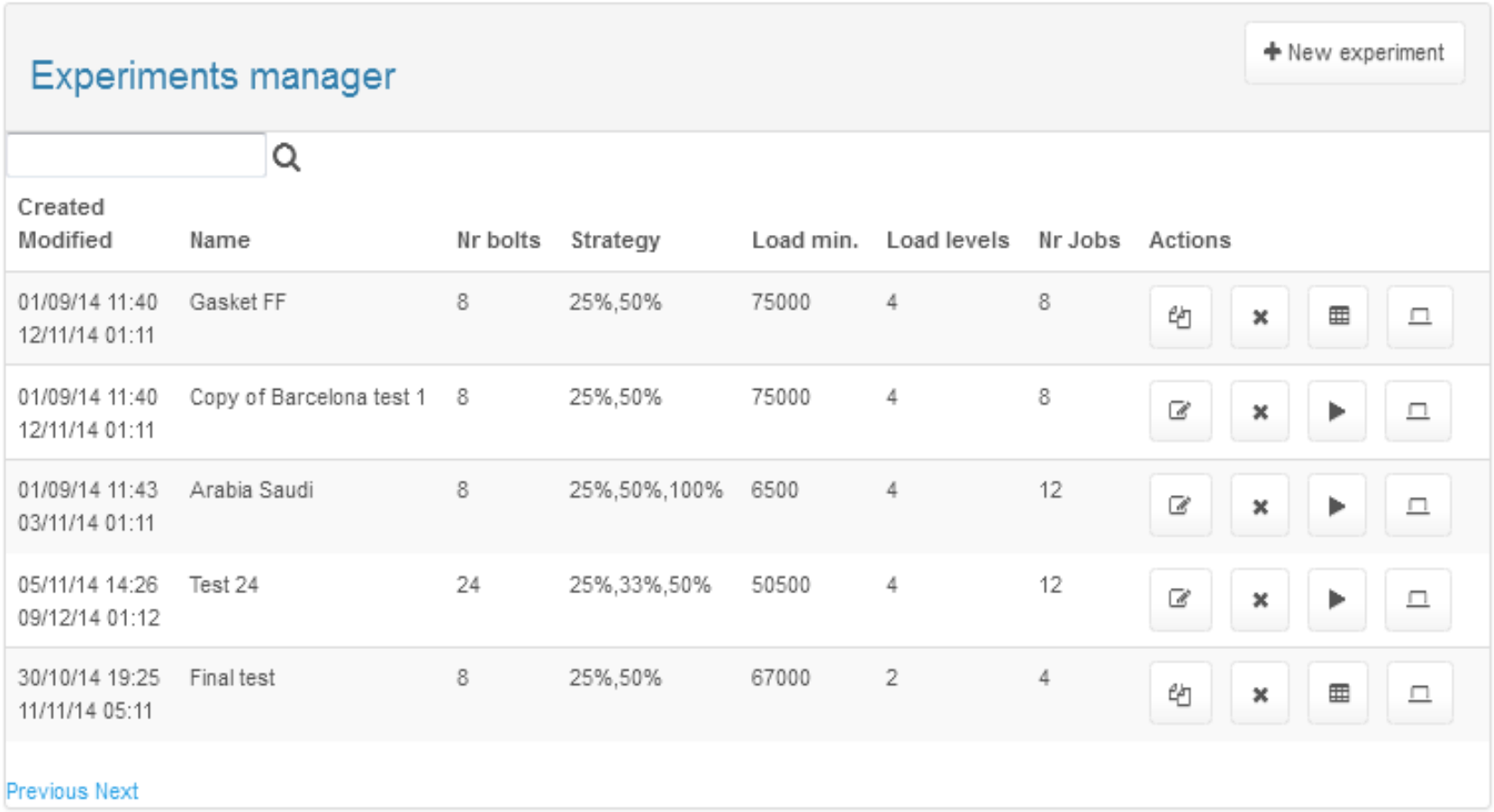
Case workflow



System architecture



GUI: Experiments manager



GUI: Define material

Material

Name

mesh name

Comments

Material properties

Young module (N/m2)

Young module

Poisson ratio

Poisson ratio

Ultimate tensile stress (MPa)

Tensile stress

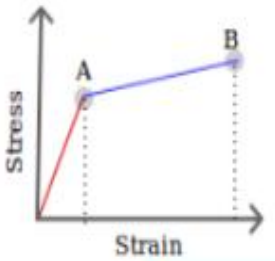
Yield Strength (MPa)

Elastic limit

B(x,y)

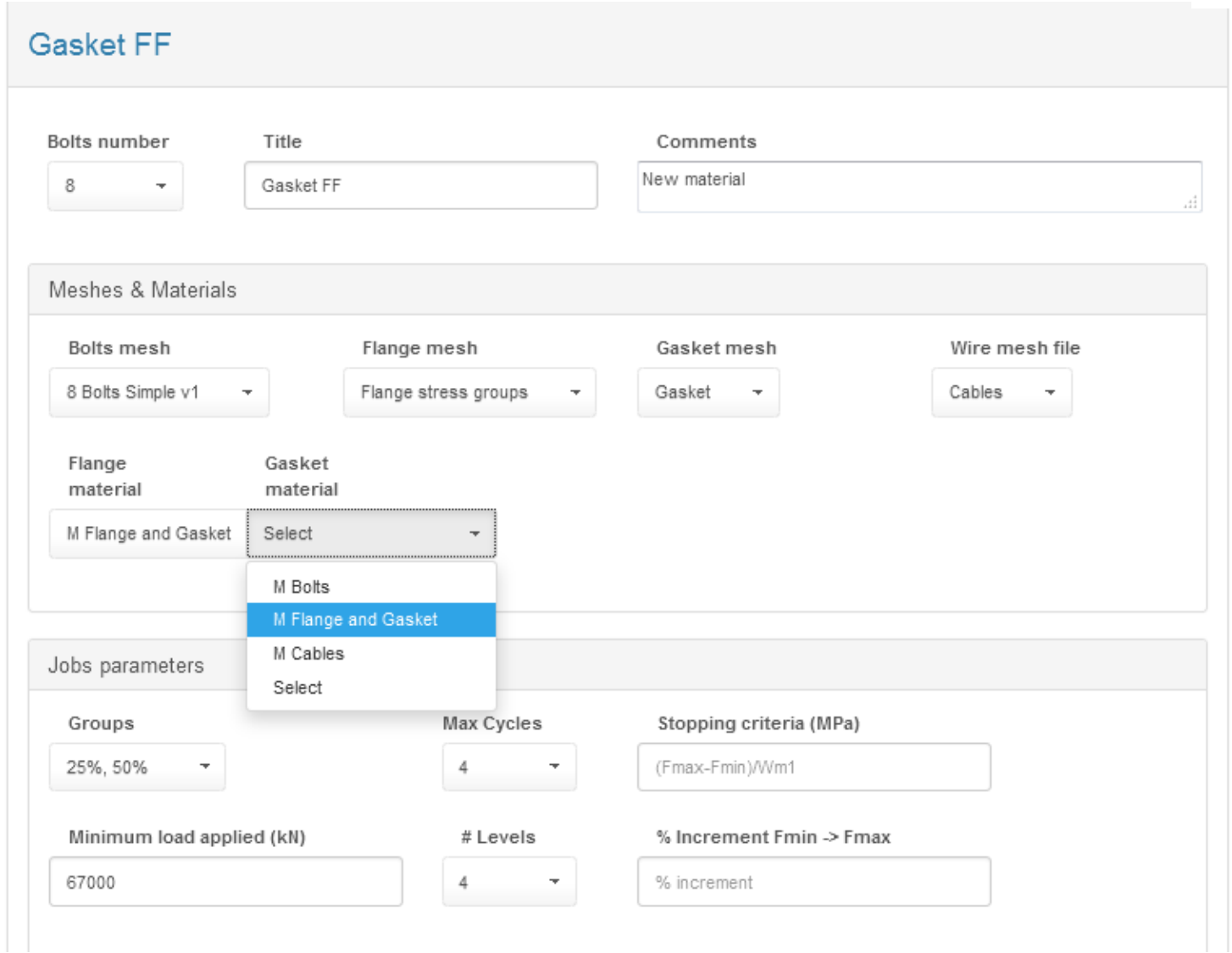
bx

by



Save material

GUI: Define simulation



GUI: Submit simulations

New Submission: Gasket FF

Submit experiment

Please check the experiment configuration before submission:

Nr of bolts: 8 **Strategy:** 25%,50% **Load min:** 67000kN **Load levels:** 4 **Increment:** 5 % **Nr jobs:** 8

Strategy 25%:

Level	FA	FB	FC	FD
1	70350kN	69234 kN	68117 kN	67000 kN
2	73868kN	71579 kN	69290 kN	67000 kN
3	77561kN	74041 kN	70521 kN	67000 kN
4	81439kN	76626 kN	71813 kN	67000 kN

GUI: Results in critical points

Gasket FF

Job 1

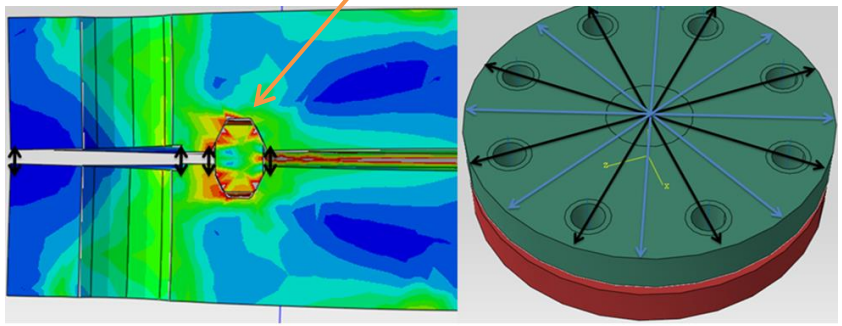
Job 2

Remote visualization

Displacements

COOR_X	COOR_Y	COOR_Z	DX	DY	DZ	DRX
8.36062E+01	4.50200E+01	5.49546E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E
2.02597E+01	4.50200E+01	9.79773E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E
8.36062E+01	4.50200E+01	5.49546E+01	3.76901E-03	-2.67562E-02	2.31844E-03	7.03716E
2.02597E+01	4.50200E+01	9.79773E+01	2.95612E-03	-5.34853E-02	1.35491E-02	4.12638E
8.36062E+01	4.50200E+01	5.49546E+01	3.48461E-03	-3.49386E-02	2.13671E-03	6.48224E
2.02597E+01	4.50200E+01	9.79773E+01	2.89821E-03	-6.19878E-02	1.32608E-02	4.03824E
8.36062E+01	4.50200E+01	5.49546E+01	3.35717E-03	-3.85014E-02	2.07394E-03	6.29036E
2.02597E+01	4.50200E+01	9.79773E+01	2.86454E-03	-6.57067E-02	1.31446E-02	4.00272E
8.36062E+01	4.50200E+01	5.49546E+01	3.30060E-03	-4.00672E-02	2.04977E-03	6.21644E
2.02597E+01	4.50200E+01	9.79773E+01	2.84803E-03	-6.73531E-02	1.30963E-02	3.98797E
8.36062E+01	4.50200E+01	5.49546E+01	3.27548E-03	-4.07585E-02	2.03988E-03	6.18617E
2.02597E+01	4.50200E+01	9.79773E+01	2.84040E-03	-6.80831E-02	1.30758E-02	3.98170E
8.36062E+01	4.50200E+01	5.49546E+01	3.26439E-03	-4.10646E-02	2.03569E-03	6.17336E
2.02597E+01	4.50200E+01	9.79773E+01	2.83702E-03	-6.84072E-02	1.30669E-02	3.97899E

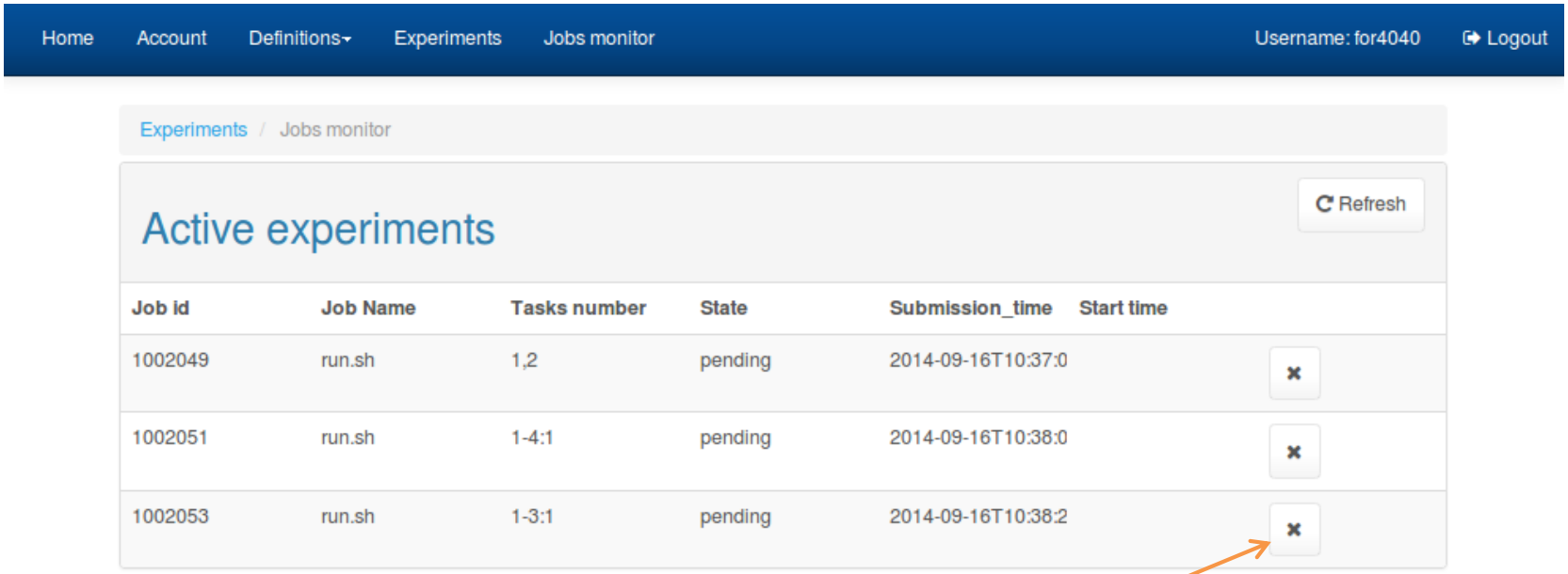
Values around the groove are critical to seal the assembly



Critical distortion points

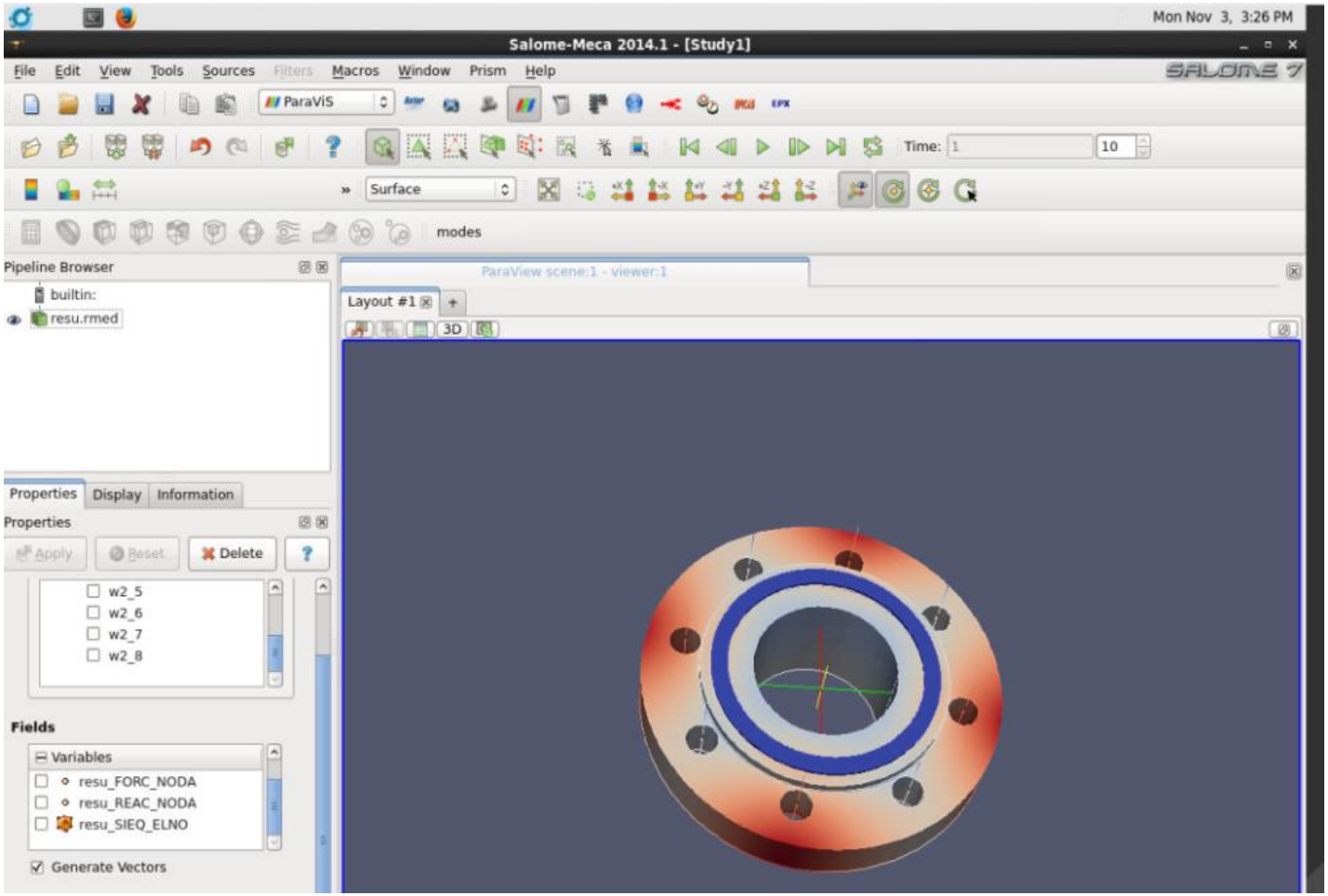
Intermediate results for each tightening step.
Job can be stopped if this results show wrong values.

GUI: Jobs monitor



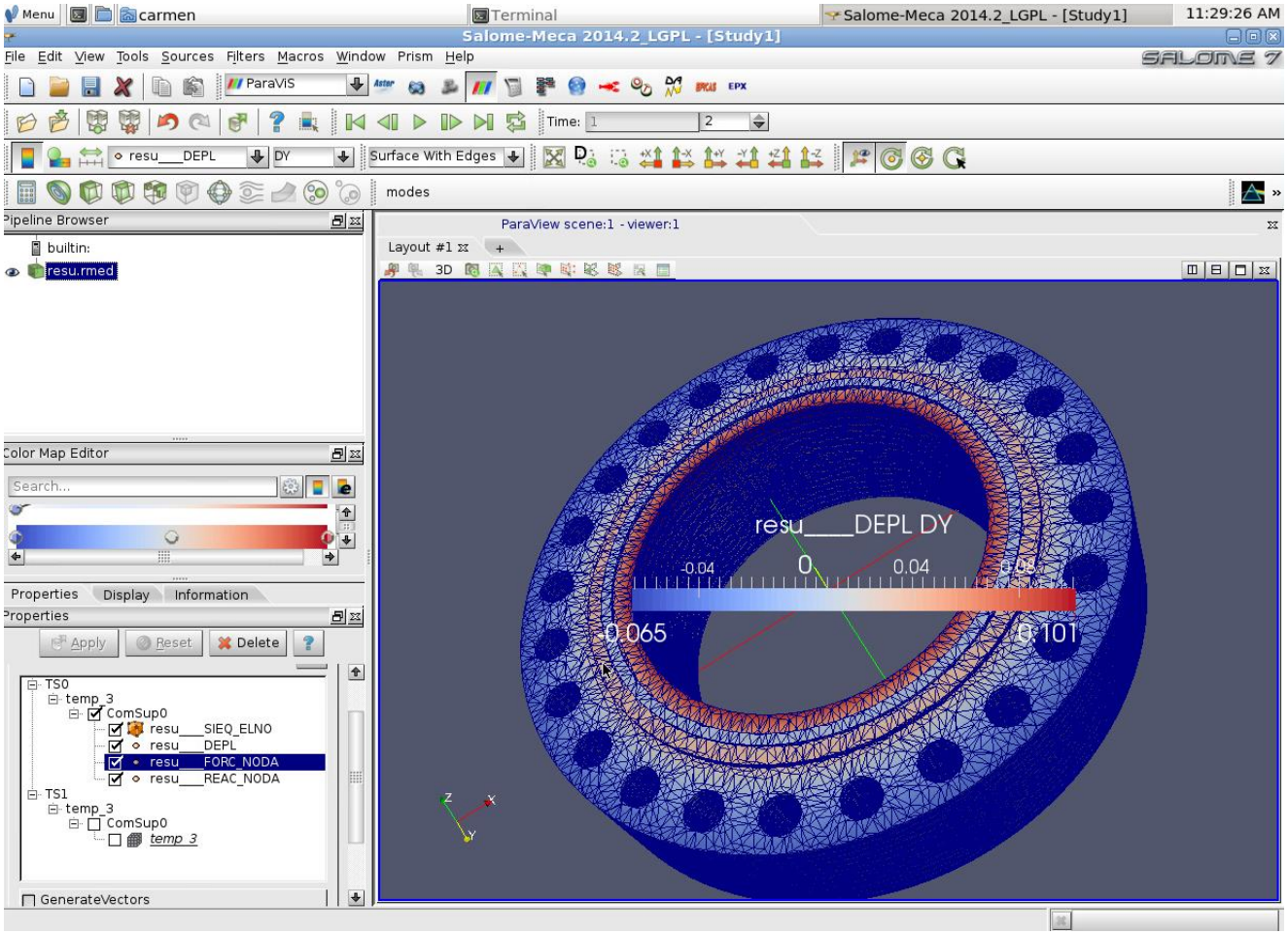
Cancel a parametric job
not the whole simulation

GUI: Remote visualization (I)

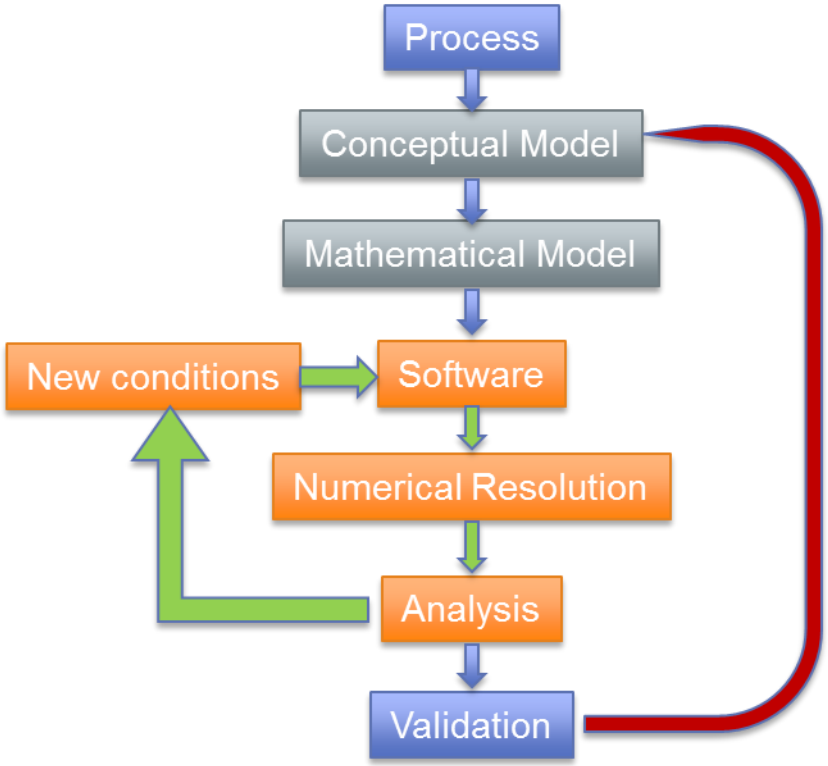


VNC client through a browser

GUI: Remote visualization (II)

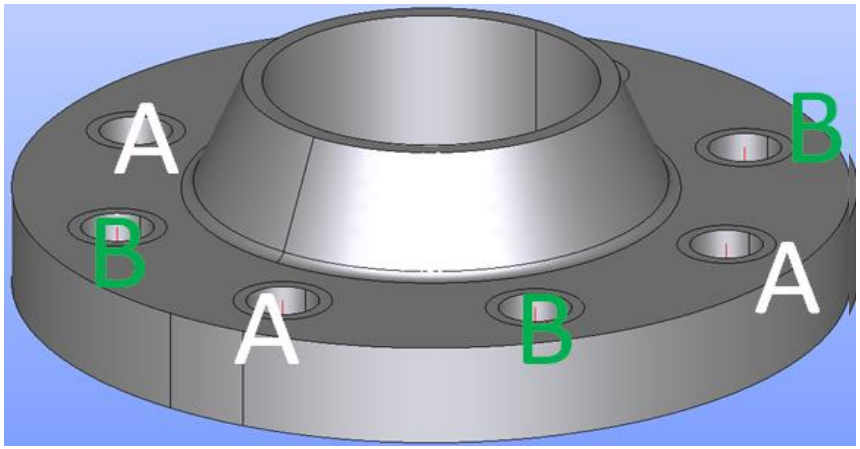


TurboVNC (high-performance version of VNC)

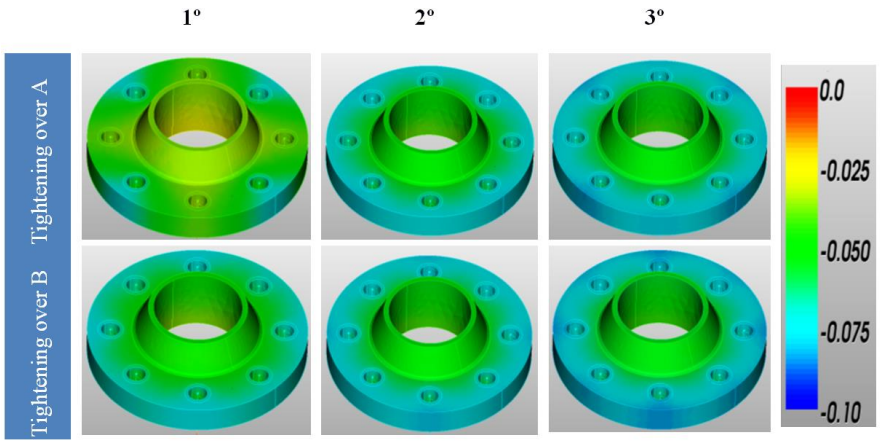


Validation
(La validazione)

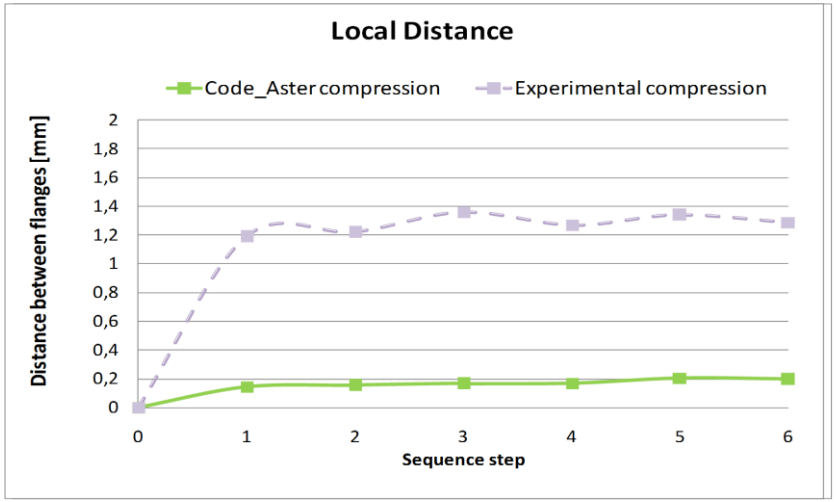
Case validation: Sensorized Flange



	1º	2º	3º
Group A	67850N	50880N	50880N
Group B	50880N	50880N	50880N



Visual result of distortion evolution [mm]



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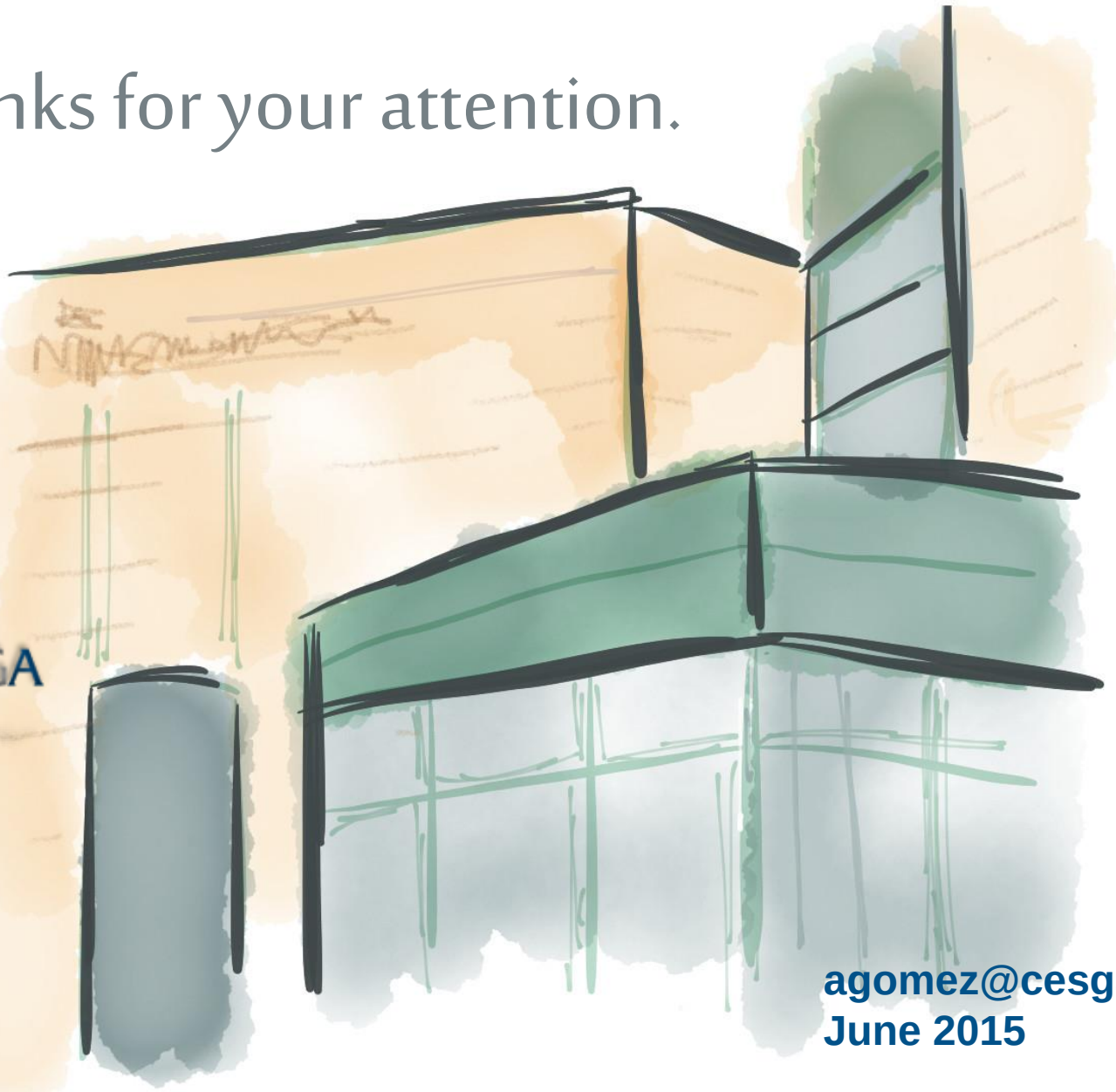
Conclusions

- Configuring the best simulation's could be a hard work for a no-expert in FEM.
- HPC resources are not only needed for simulations which need a high number of cores each one. Several multicore's (~16) simulations are needed for running parametric jobs (up to 16).
- Troubles appears very often and they are due to different issues: mesh, contacts definition, algorithms involved, software issues or MPI libraries.
- SMEs need validate their models against real cases.
- End-user prefers a GUI application and it must be flexible to incorporate new functionalities.
- Remote visualization is desirable. Best tool to visualize data depends on the output size.
- Value-added services are really needed as FORTISSIMO proposes.

Thanks for your attention.



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