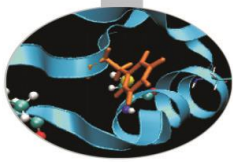
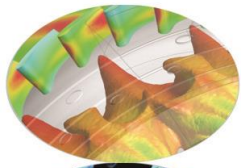
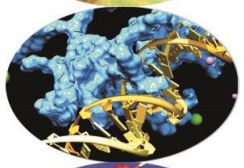
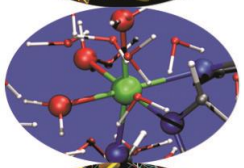
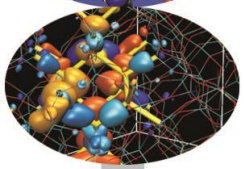
CINECA SCAI
SuperComputing Applications and Innovation



HPC Computer Aided Engineering @ CINECA

Raffaele Ponzini Ph.D.
CINECA
SuperComputing Applications
and Innovation Department – SCAI

16-18 June 2014

PRACE
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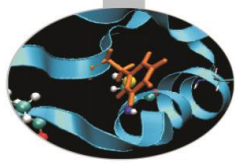
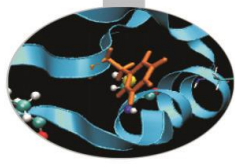


Outline

- Computer Aided Engineering
- Engineering tools: Experimental vs Numerical
- HPC Platforms and CAE applications
- CAE applications at CINECA

Computer Aided Engineering



[From Wikipedia, the free encyclopedia]

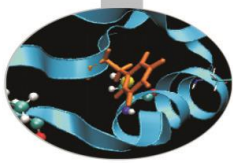
Computer-aided engineering (CAE) is the broad usage of computer software to aid in engineering analysis tasks. It includes:

- Finite Element Analysis (FEA),
- Computational Fluid Dynamics (CFD),
- Multi-body dynamics (MBD),
- Optimization

Software tools that have been developed to support these activities are considered **CAE tools**.

CAE tools are being used, for example, to **analyze** the robustness and performance of components and assemblies. The term encompasses **simulation, validation, and optimization** of products and manufacturing tools.

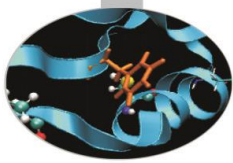
In the future, CAE systems will be major providers of information to help support design teams in **decision making**.[…]



Computer Aided Engineering

CAE areas covered include:

- Stress analysis on components and assemblies using FEA (Finite Element Analysis);
- Thermal and fluid flow analysis Computational fluid dynamics (CFD);
- Multi-body Dynamics (MBD) & Kinematics;
- Analysis tools for process simulation for operations such as casting, molding, and die press forming
- Optimization of the product or process

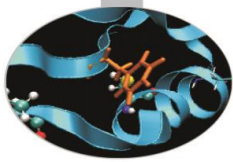


Computer Aided Engineering

In general, there are three phases in any computer-aided engineering task:

- **Pre-processing** – defining the geometry model, the physical model and the boundary conditions
- **Computing** (usually performed on high powered computers (HPC))
- **Post-processing** of results (using scientific visualization tools & techniques)

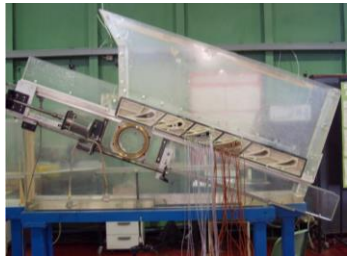
This cycle is iterated, often many times, either manually or with the use of automation techniques or using optimization software.



Computer Aided Engineering

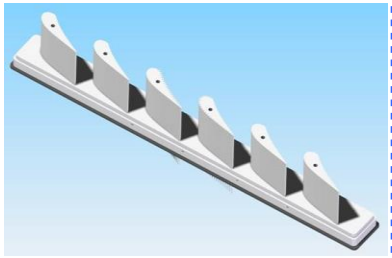
PRE-PROCESSING → **COMPUTATION** → **POST PROCESSING**

PHYSICAL



MODEL

COMPUTATIONAL

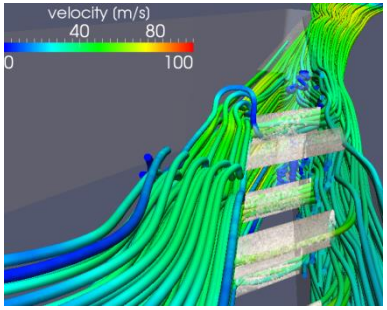


MODEL

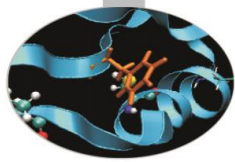
SOLVING

HPC ENVIRONMENT

VISUALIZATION

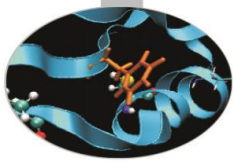


RESULTS



Engineering tools: Experimental & Numerical

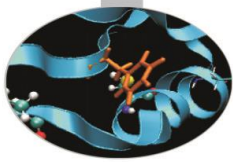
- Wind-tunnel
- Towing tank
- Biological systems



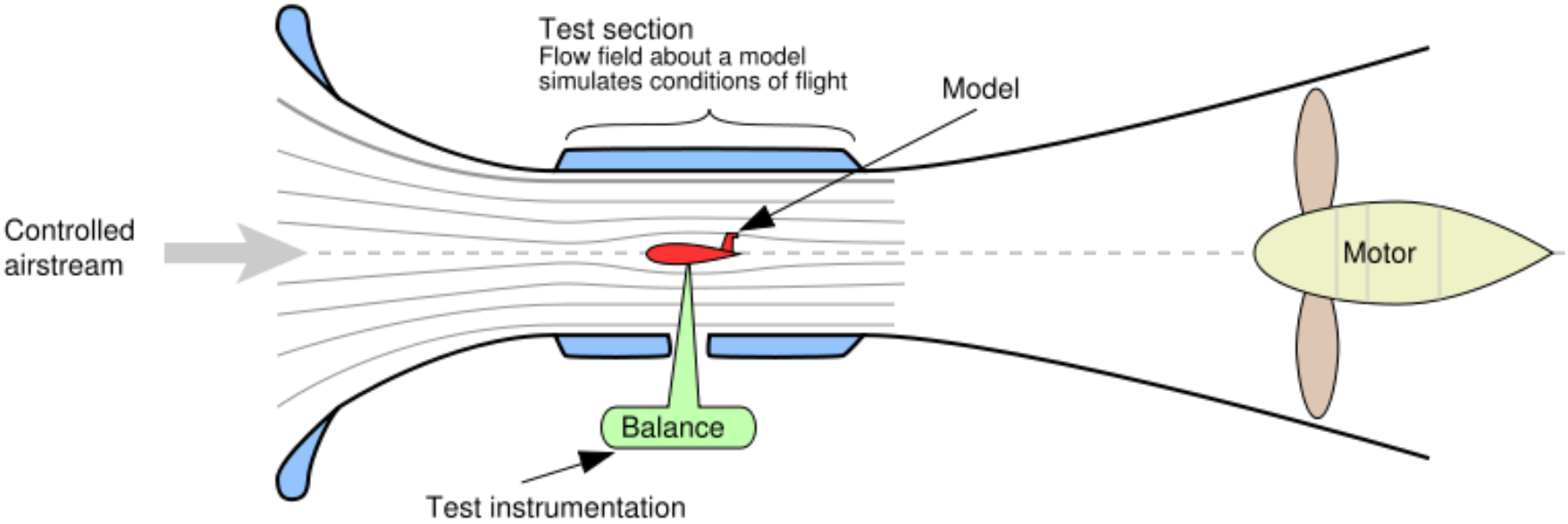
Engineering tools: Experimental & Numerical

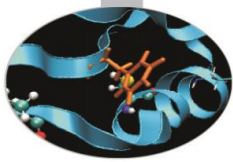
Wind tunnels are large tubes with air moving inside. The tunnels are used to copy the actions of an object in flight. Researchers use wind tunnels to learn more about how an aircraft will fly. NASA uses wind tunnels to test scale models of aircraft and spacecraft. Some wind tunnels are big enough to hold full-size versions of vehicles. The wind tunnel moves air around an object, making it seem like the object is really flying.

How Do Wind Tunnels Work?
Most of the time, powerful fans move air through the tube. The object to be tested is fastened in the tunnel so that it will not move. The object can be a small model of a vehicle. It can be just a piece of a vehicle. It can be a full-size aircraft or spacecraft. It can even be a common object like a tennis ball. The air moving around the still object shows what would happen if the object were moving through the air. How the air moves can be studied in different ways. Smoke or dye can be placed in the air and can be seen as it moves. Threads can be attached to the object to show how the air is moving. Special instruments are often used to measure the force of the air on the object.



Engineering tools: Experimental



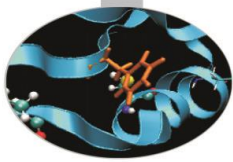


Engineering tools: Experimental

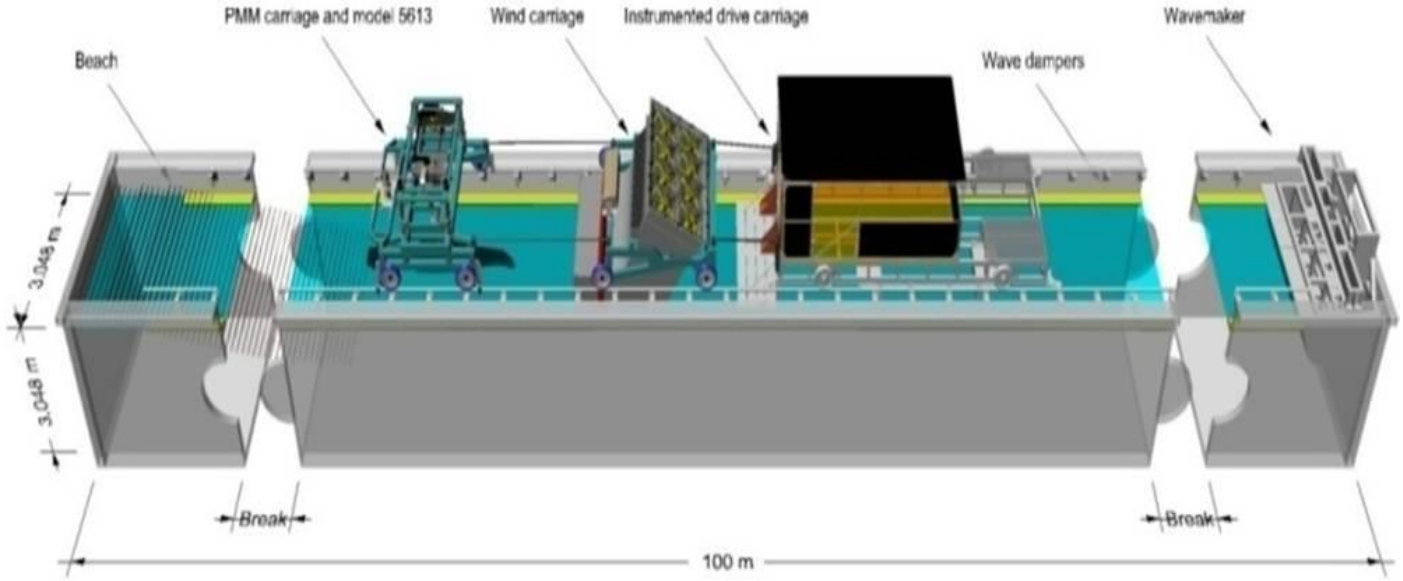
NACA+PLATE: https://www.youtube.com/watch?feature=player_embedded&v=q_eMQvDoDWk

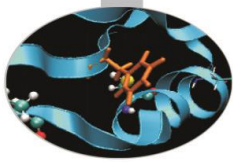
Turbulence: https://www.youtube.com/watch?v=SXwVyxorvno

Drag: https://www.youtube.com/watch?v=gHFFZ1ru0Pk&list=PLdV0RxlPNNZqL8-DGn4K6noNNewl3e9l-



Engineering tools: Experimental





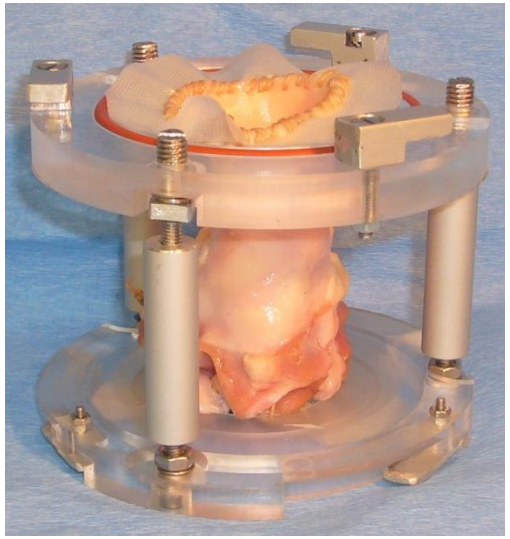
Engineering tools: Experimental

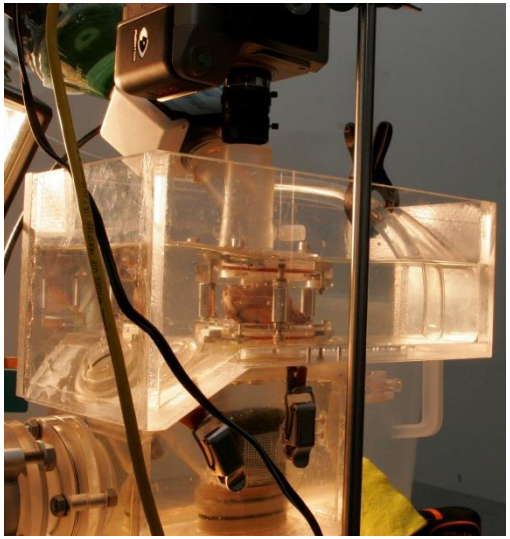
Ship hydrodynamics: https://www.youtube.com/watch?v=iHGGSdGM7Xk

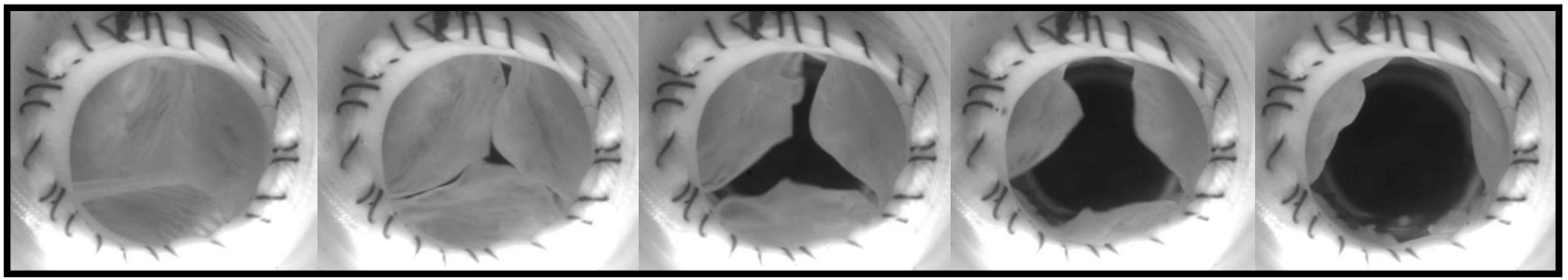
Hydrofoil: https://www.youtube.com/watch?v=ww8vJgAir3U

Drag: https://www.youtube.com/watch?v=4q5ffroIMMc

Engineering tools: Experimental



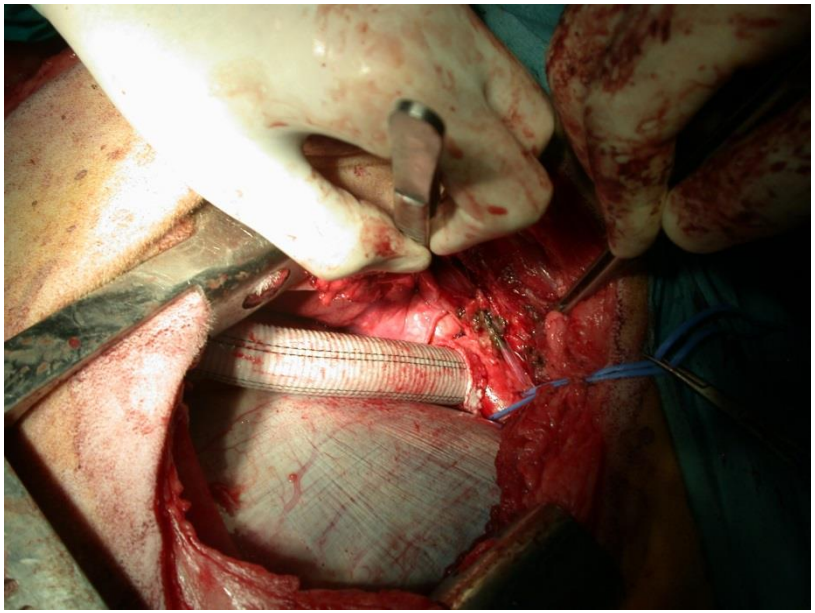


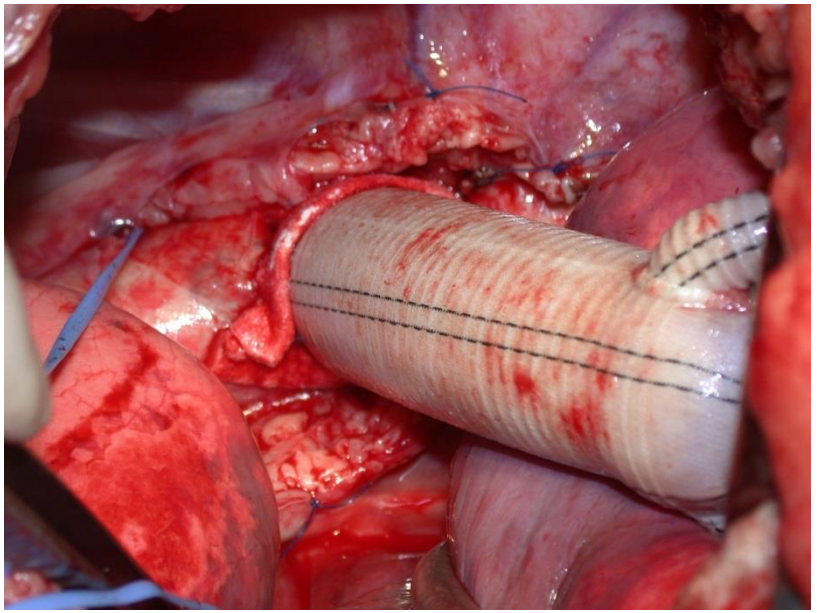


0 ms | 19.26 ms | 24.88 ms | 28.09 ms | 33.71 ms

Courtesy of Riccardo Vismara Politecnico di Milano

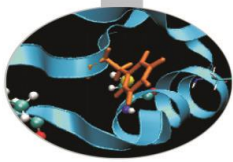
Engineering tools: Experimental

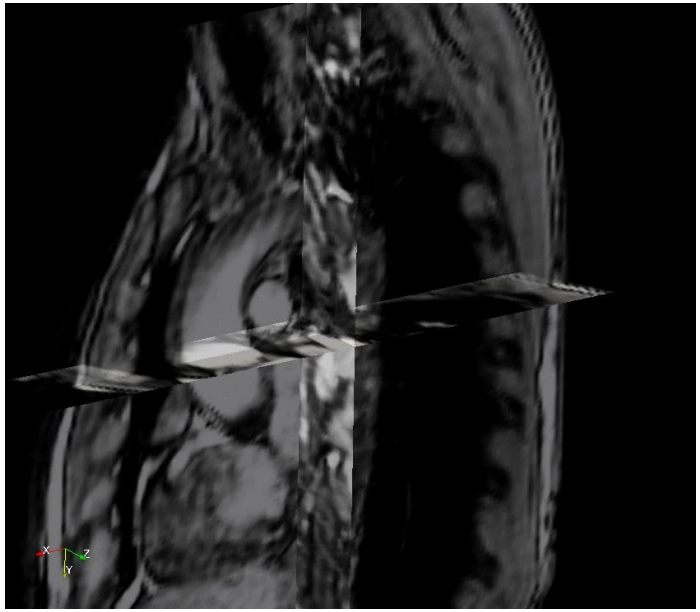


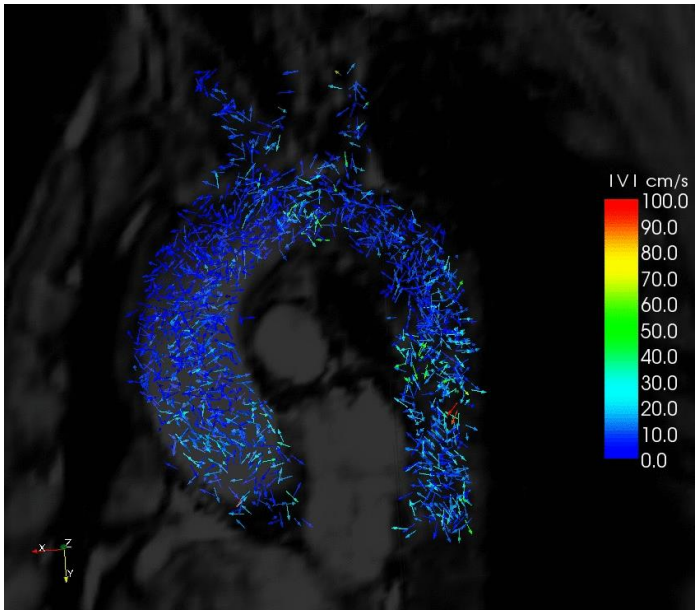


Courtesy of: Fabio Acocella & Stefano Brizzola
Dipartimento Di Scienze Cliniche Veterinarie
Facolta' Di Medicina Veterinaria
Universita’ Degli Studi Di Milano

Engineering tools: Experimental

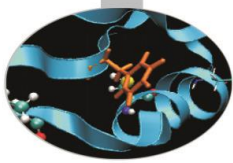






Courtesy of Giovanna Rizzo IBFM CNR

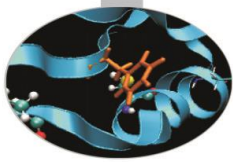
Engineering tools: Experimental and CAE



	Wind tunnel	Towing tank	CAE
Costs	10-100 k€ (*)	1-10 k€ (**)	1-10 k€
Time to data	weeks	days	hours
Peoples	5-10	5-10	1-3
Repeatability	Medium	Medium	High
Source of uncertainty	High	High	Medium
Accuracy	Medium	Medium	TBD

(*) http://www.uwal.org/customer/rateguide.htm
(**) http://en.openei.org/wiki/Ship_Towing_Tank

Engineering tools: Experimental and CAE

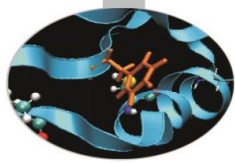


The main difference between experiments and virtual tools is in that:

- Virtualization of physical phenomena requires very often a simplification of the problem, of both geometry and fluid properties, in order to allow to solve the related numerical problem (accuracy)
- Experiments contains much more complexity related to the physical phenomenon and are therefore considered a reference misconsidering the weigth of source of errors, noise, level of control on the physical quantities involved by the experiment, the repeatability and the data acquirable during an experiment (repeatability)

A constructive interplay of experimental and virtualized models is of capital interest for modern engineering

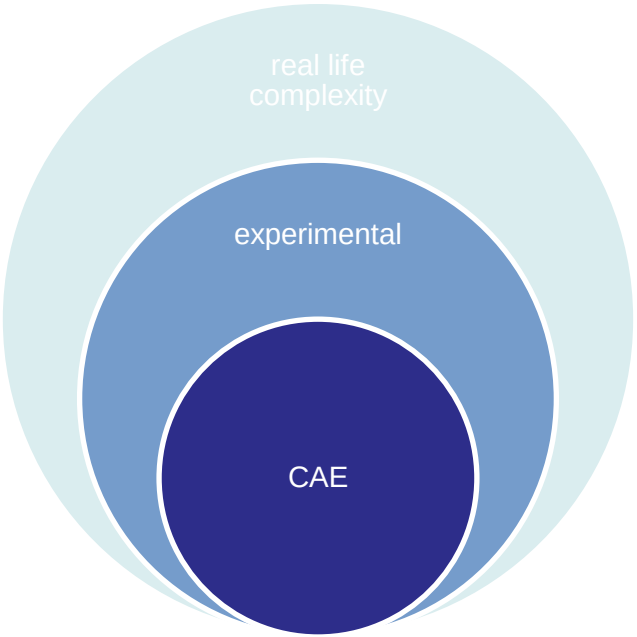
Engineering tools: Experimental and CAE

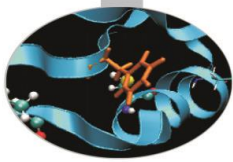


A constructive interplay of experimental and virtualized models is of capital interest for modern engineering.

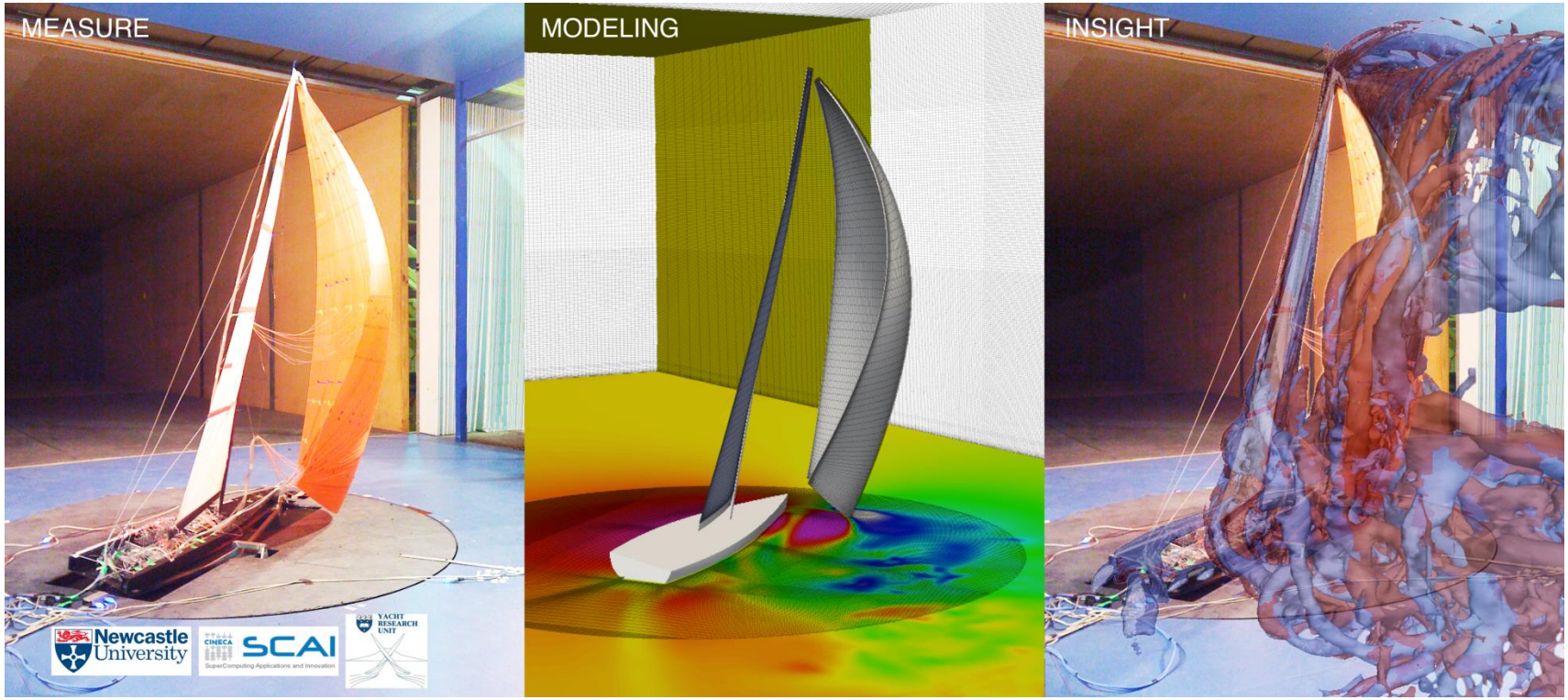
Reduce problem complexity in order to control the phenomenon,quantify by mean of measures, design and decision making.

Looking with this kind of perspective experiments and CAE models are going on the same direction.

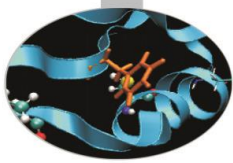




HPC Platforms and CAE applications

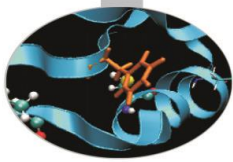


http://www.ignazioviola.com/ignaziomariaviola/home_files/Viola_INNOVSAIL2013.pdf



HPC Platforms and CAE applications

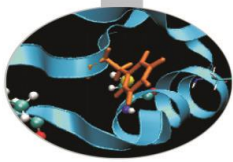
The design team of Luna Rossa Challenge beside taking advantage of large amount of CINECA HPC resources, both in term of computing and remote visualization, for design data production, has undertaken in year 2012 with CINECA a 12 months feasibility study for the evaluation on the same analyses of the OpenFOAM (Open Source Field Operation and Manipulation) library on high performance computing platforms.



HPC Platforms and CAE applications

The American Food and Drug Administration has promoted a wide inter/laboratory study to assess the usability of CFD for implantable design in hemodynamics (2012 Assessment of CFD Performance in Simulations of an Idealized Medical Device: Results of FDA's First Computational Inter- laboratory Study)

HPC Platforms and CAE applications



Once virtualization is recognized to be cost/effective and reliable new trends are incoming for R&D in engineering applications:

- Several CAE software vendor is now pushing towards CFD analysis (Hyperworks and Abaqus included CFD add-on in their application platform)
- Visualization is a key turn point thanks to very rich datasets 3D/4D and is now of great interest for all sw vendor
- Automation for data production
- Data analysis MKL by Ansys and Teclplot360 for advanced data analysis
- Optimization: Design Of Experiment , adjoint solver
- Cloud computing

Computational platforms today must be considered a commodity, always available, scalable as needed in order to face CAE issues in a proper way

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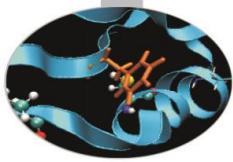
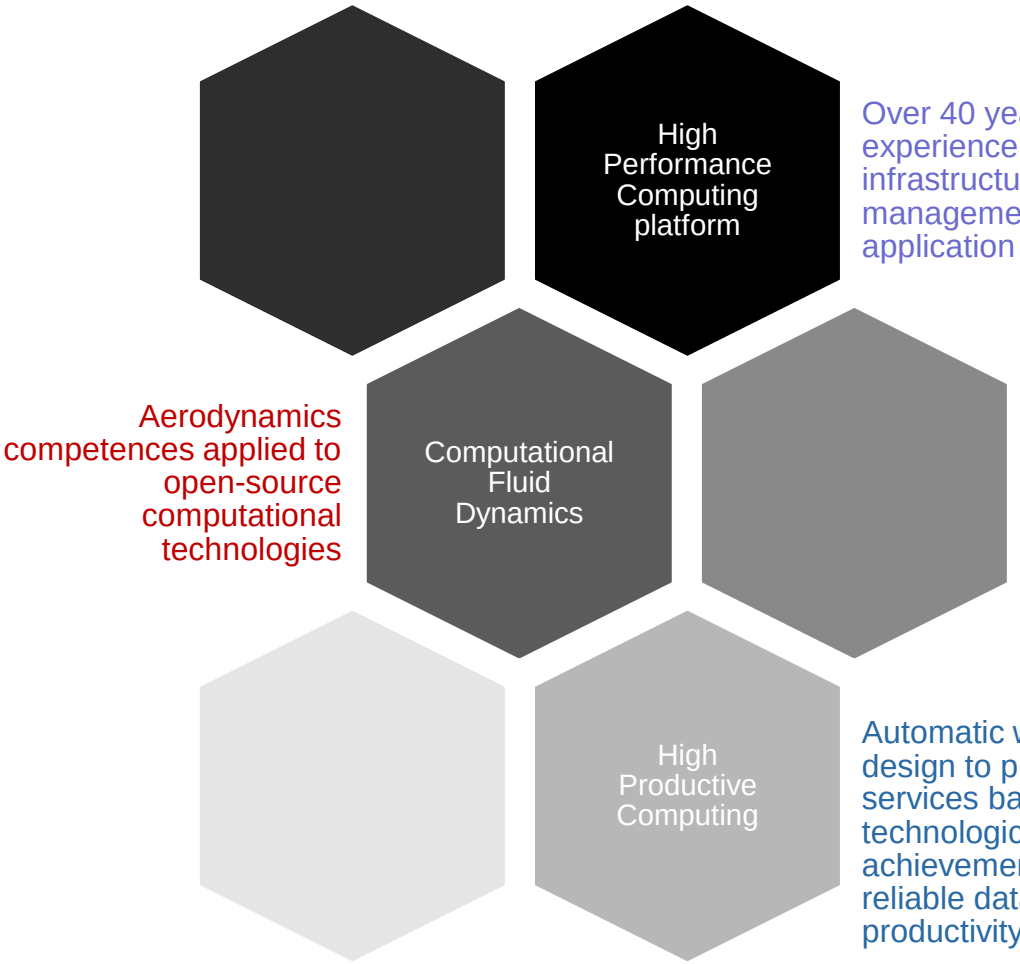
CAE application at CINECA



CINECA is the largest computing centre in Italy, is a not for profit Consortium, made up of 69 Italian Universities, three National Institutions and the Ministry of Education and Research.

SCAI (SuperComputing Applications and Innovation) is the High Performance Computing department of CINECA. The mission of SCAI is to accelerate the scientific discovery by providing high performance computing resources, data management and storage systems and tools and HPC services and expertise at large, aiming to develop and promote technical and scientific services related to high-performance computing for the Italian and European research community.



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CAE application at CINECA

Top500 ranked HPC infrastructure

Fermi is ranked #15 on the latest top500 list (nov.'13)

Green500 ranked HPC infrastructure

Eurora is ranked #98 on the latest green500 list (nov.'13)

Dedicated HW for pre/post processing CAE activity

Dedicated 'Fat' nodes enables the management of up to 1TB of shared RAM

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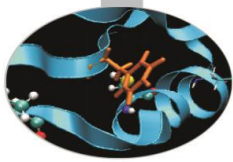
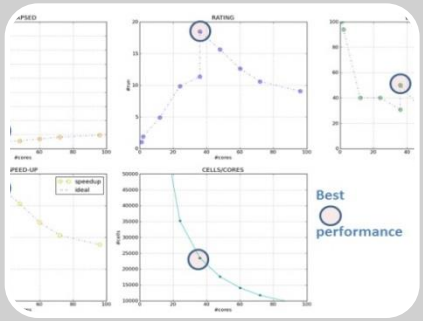
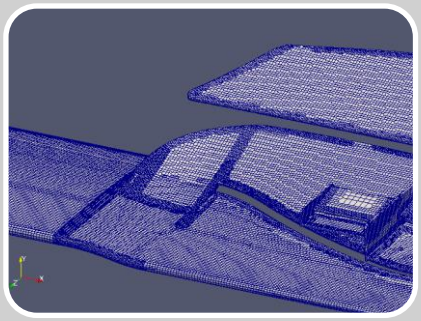
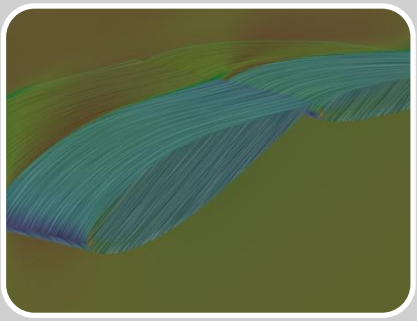
CAE application at CINECA









Tailored Scalability

Performance indices, including rating, speed-up and efficiency are evaluated for specific cases and settings

Mesh automation

Highly automated meshing process of 3D complex shapes is obtained using scripting techniques applied to open-source and third-party software

Automatic post-processing and reporting

Automated quantitative and qualitative post-processing, visualization and reporting is obtained using Python programming scripting techniques and open-source software and libraries

Web-based interfaces

Overall workflow, computational platforms and tools are available thru modern and flexible web-based technologies for a remote high productive experience

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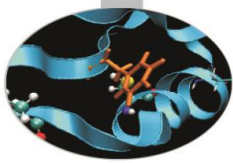

Main scope of the course

During the course we will focus on:

- CFD applications: external aerodynamics, marine hydrodynamics
- Open-source tools: SnappyHexMesh, OpenFOAM (OpenCFD ltd.), Paraview (Kitware Inc.)
- HPC platforms: overview of distributed infrastructure and added value to speed-up the design process and time-to-result
- Productivity: automation, Design Of Experiment, Optimization

Intent of the course is to give a correct, technical and scientific definition of the topics but using a plain speak (without oversimplifying) in order to give to the students a taste of the practical issues encountered when dealing with this kind of problem in day by day work.