
ff4EuroHPC

Copernicus

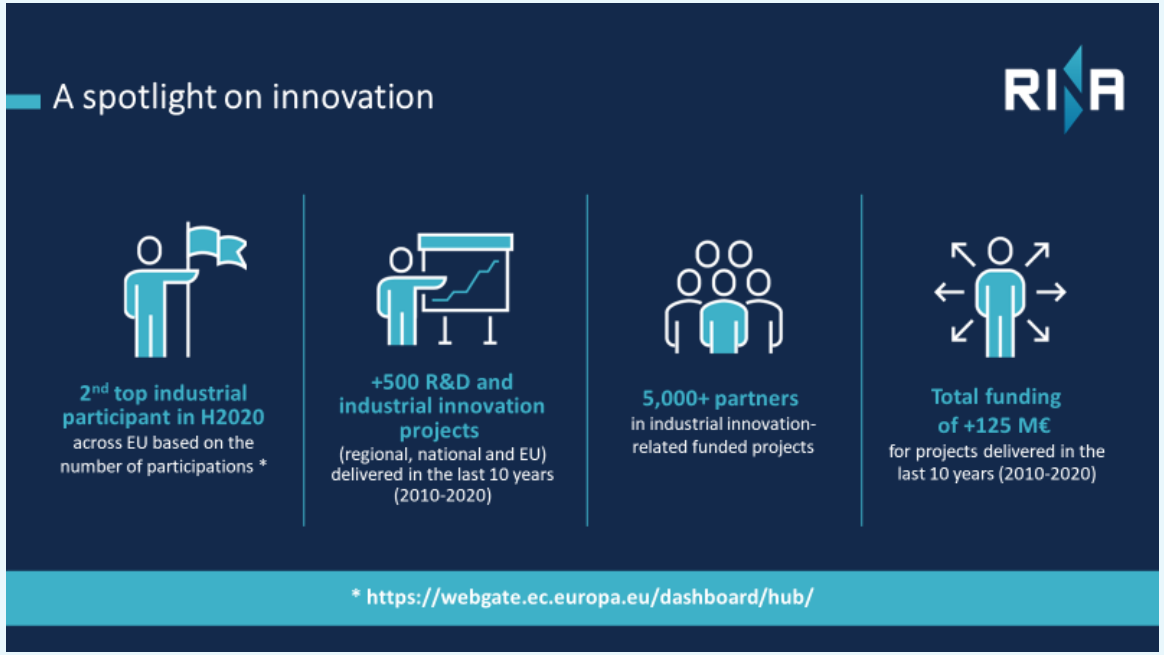
Cloud-based HPC platform to support systemic-pulmonary shunting procedures

Emiliano Costa, RINA

Outline

- Introduction
- Development
- Final considerations
- Conclusions

RINA at a glance

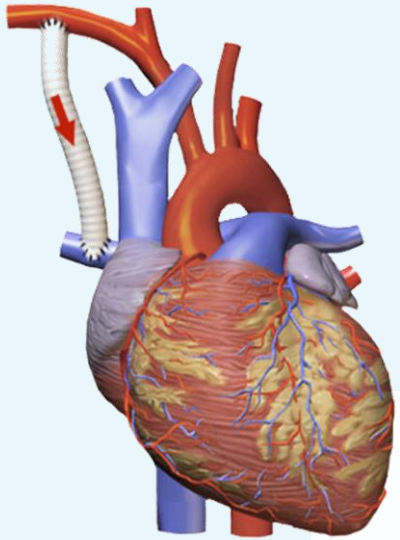


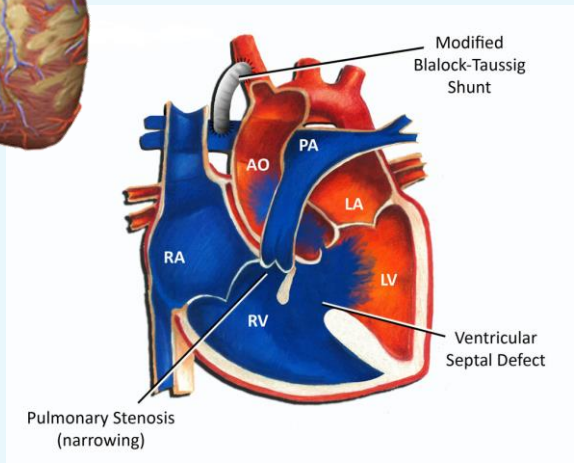
Introduction:
Experiment Consortium & Roles

Partner	Acronym	Role	Logo
InSilicoTrials Technologies SpA	IST	Industrial end-user	
RBF Morph Srl	RBF	Technology expert, ISV	
Fondazione Toscana Gabriele Monasterio	FTGM	Application expert, Clinical end-user	
RINA Consulting	RINA-C	Technology expert	
CINECA	CINECA	HPC expert, Host Centre	

Introduction: The Problem

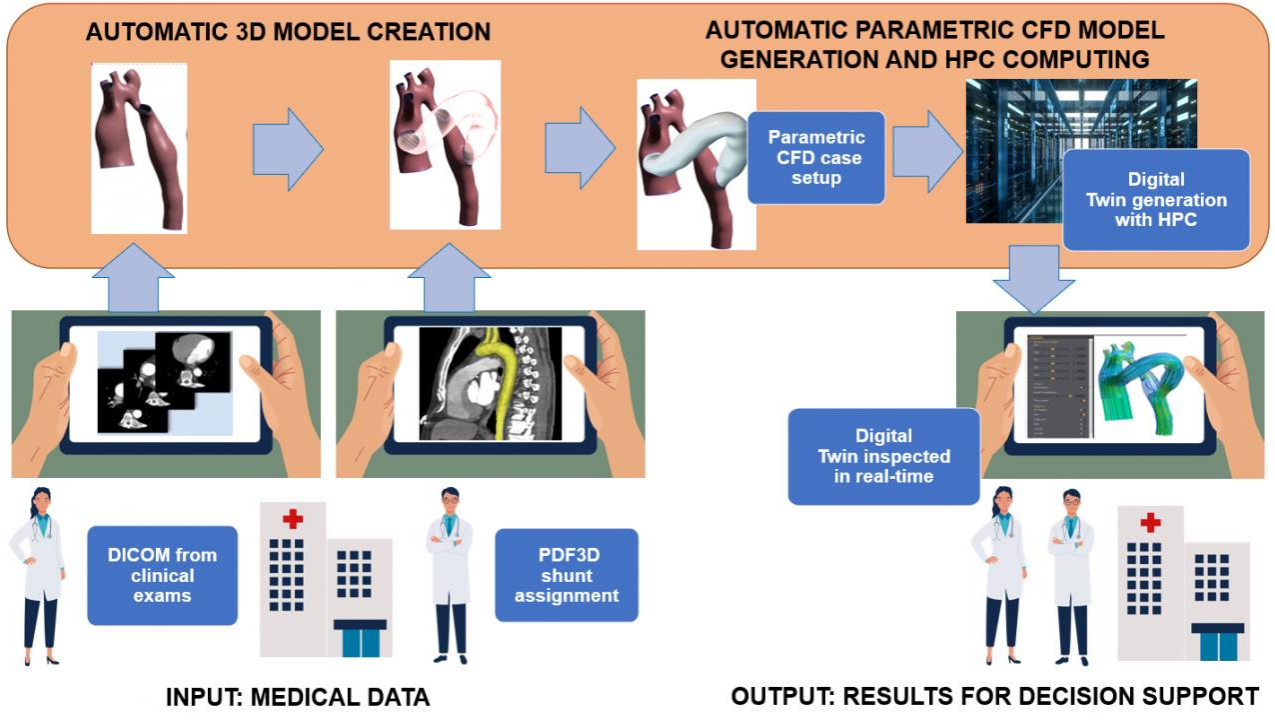
- **Congenital heart diseases** (CHDs) account for nearly **one-third** of all congenital birth defects and **7th cause of death** in children younger than 1 year in 2017 .
- Without the ability to alter the prevalence of CHD, interventions and resources must be focused to **improve survival** and **quality of life**.
- The **Modified Blalock Taussig Shunt** (mBTS) is a common **palliative operation** on cyanotic heart diseases, but it is associated with **significant mortality** (~7,2%).



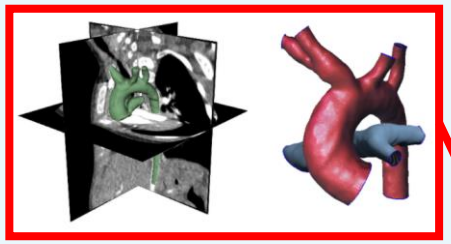


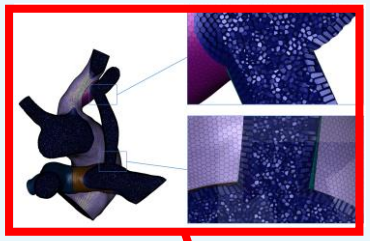
Introduction:
Experiment Approach & Expected Outcome

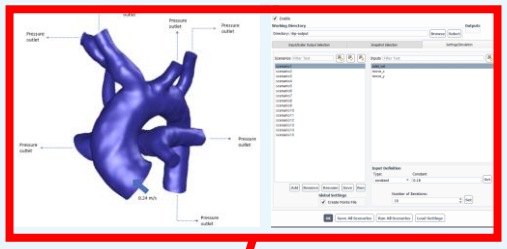
- The Copernicus application aims to provide an interactive **Medical Digital Twin** (MDT) of the patient-specific district to **support the surgery planning of mBTS under critical conditions**.
- The procedure was designed considering **advanced numerical means** with the objective to deploy MDT within ~**48hh**.

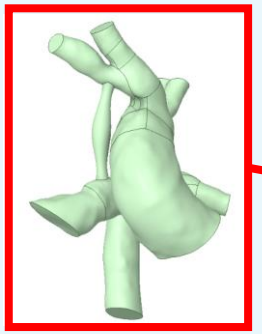


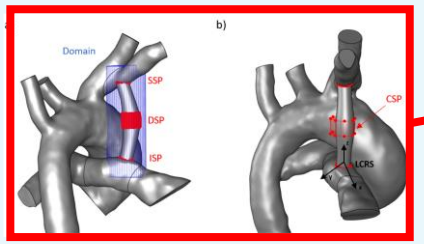
Developement:
Copernicus workflow and numerical means











CT Image Segmentation (Python Code)

CAD Reconstruction + Shunt creation (SpaceClaim)

Surface and volume Mesh generation (Fluent – Watertight)

CFD and Snapshot set-up (Fluent – RBP)

RBF Shape modifiers set-up (Fluent – RBF Morph)

HPC for Snapshot generation (Fluent – RBF Morph

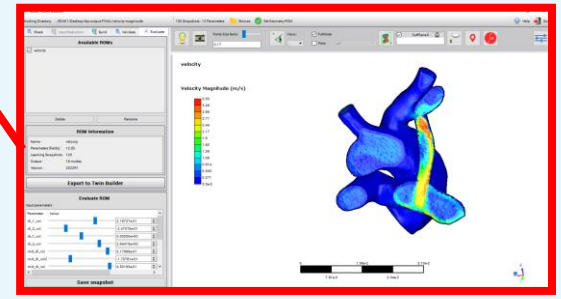
ROM Generation (Twin Builder)

ROM Evaluation (Twin Builder)

Copernicus Pre-Processing

Copernicus Computing

Copernicus Post-Processing



Developement:
Copernicus numerical scenario for MBTS

Copernicus numerical case scenario for mBTS consists of the set-up of the framework to create an **accurate ROM(*) valuable from medical point of view**.

Such scenario foresaw:

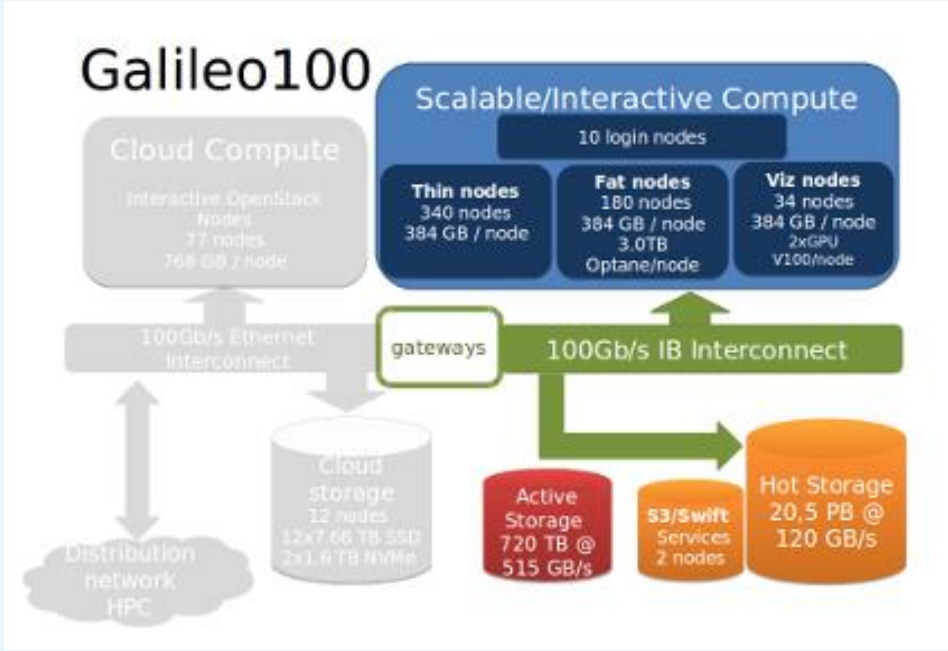
- Creation of a **high-fidelity CFD case** of the medical district (~2 million cells)
- Creation of a suitable number of **RBF shape modifiers** with medical significance (#12)
- Set-up of **DoE** with a suitable number of design points (#150)
- Identification of the proper number of **computing processes** to use for CFD computing (#36)

(*) Kardampiki, Eirini et al., 2022. "The Hemodynamic Effect of Modified Blalock–Taussig Shunt Morphologies: A Computational Analysis Based on Reduced Order Modeling" Electronics 11, no. 13: 1930. https://doi.org/10.3390/electronics11131930

Development:
HPC environment and computing set-up

Main IT developments on HPC:

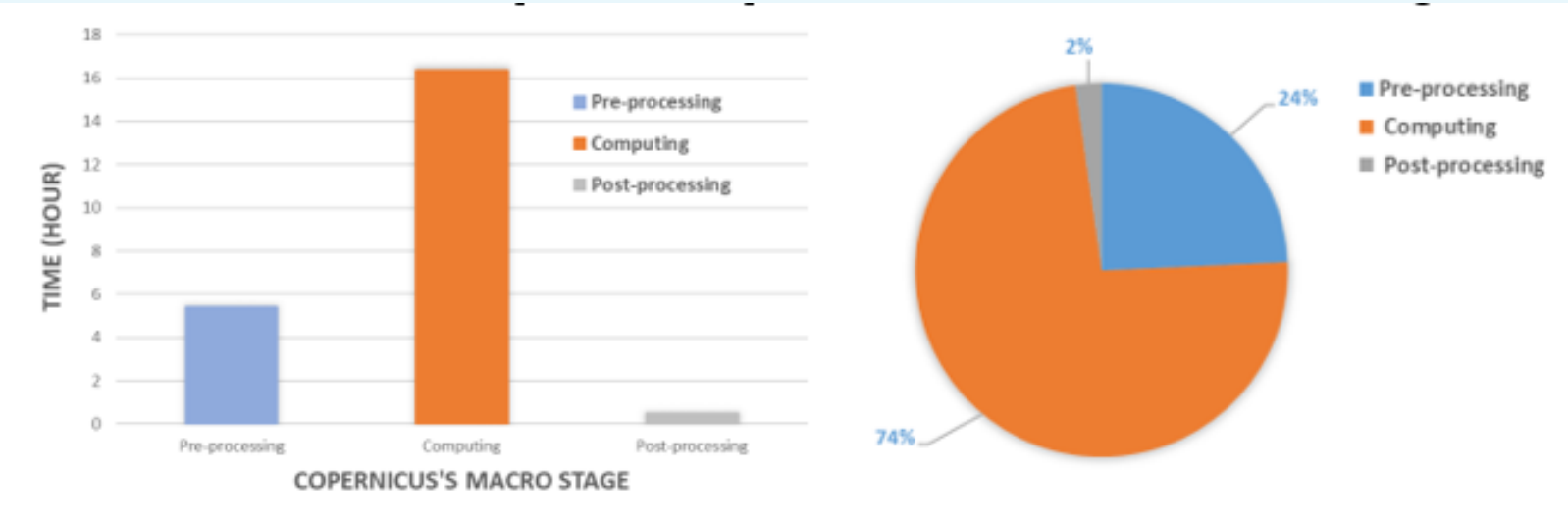
- **Set-up of the HPC environment** on the **Galileo 100** infrastructure of CINECA to carry out the **Copernicus's computing** stage.
- Implementation of the **multi-node strategy** to **automatically** enable calculations of **sets of snapshots in parallel** on **HPC** using the **Slurm** Workload Manager.



Development:
Results gained with HPC computing

The results gained with the **single-node strategy** to automatically run sequential CFD calculations on a **single node**, are reported below.

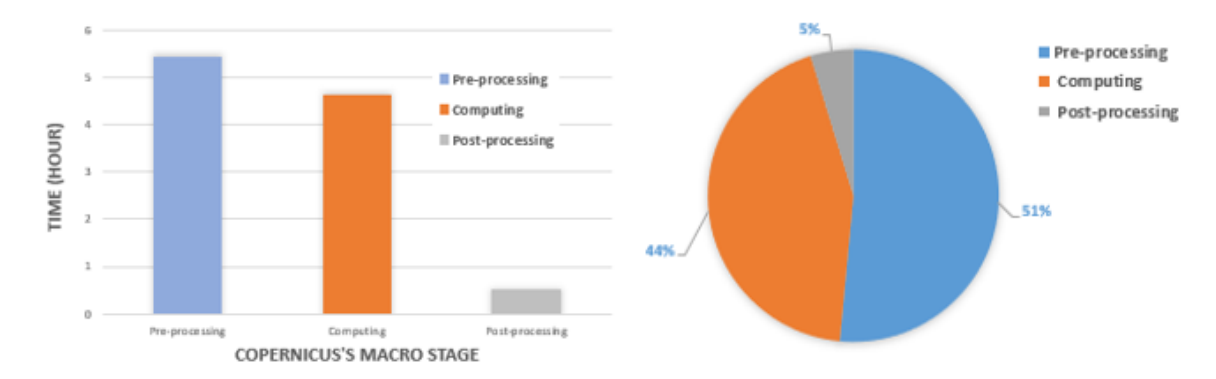
Whole workflow duration: **22hh**.

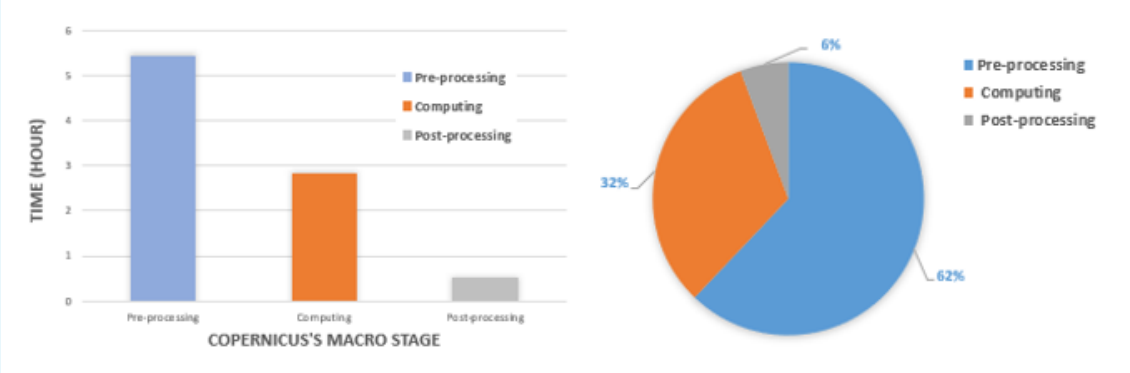


Development:
Results gained with HPC computing

The results gained with the **multi-node strategy** to automatically run sets of sequential CFD calculations on a **different nodes**, are shown below.

Results refer to the studies performed using 3 and 5 licenses of the CFD solver and morpher tool in parallel.



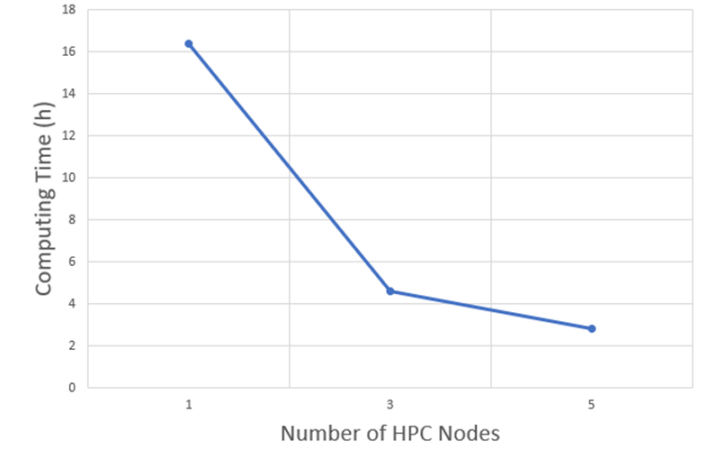


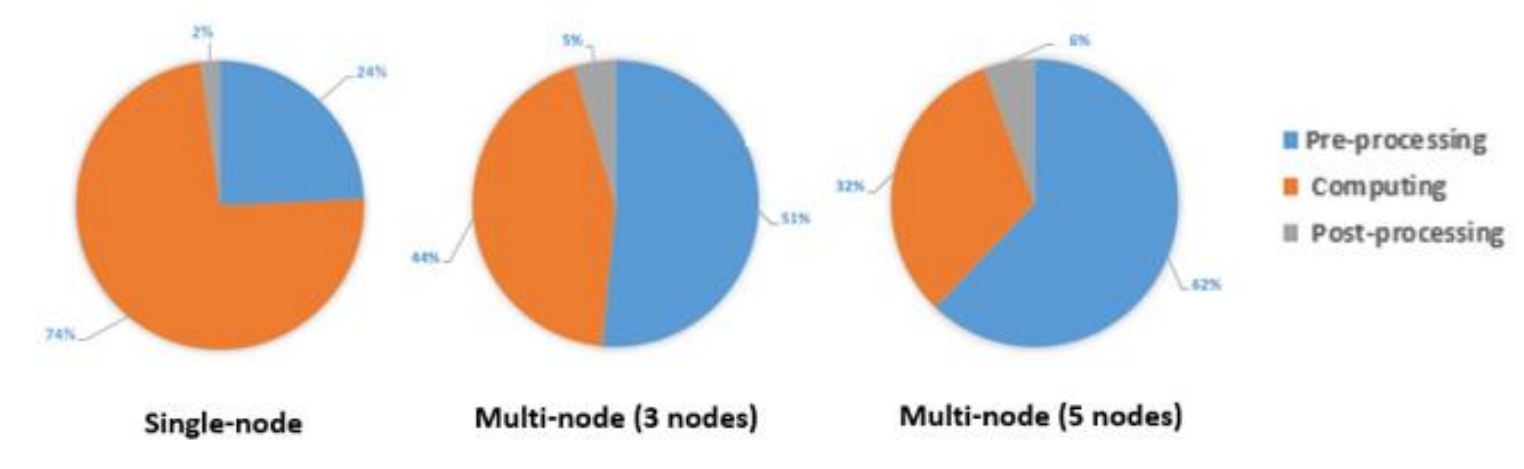
Development:
Results gained with HPC computing

Comparison between the results gained adopting the single-node and multi-node strategy is shown below.

Exploiting all (5) licenses available, the computing time was covered just in **3hh** approximatively.

Whole workflow duration: **9hh** (<< **48 hh**).





Final considerations: Main results achieved

- **Integrated and effective numerical procedure** to generate a ROM of a patient-specific vascular district in which the shunt implantation is geometrically parameterized
- Set-up of the **Copernicus numerical case scenario**
- **Completion** of the whole Copernicus workflow in **less than 48 hours**
- Demonstration of the **competitive advantage** of the **massive use of HPC**
- Generation of a **Business model** and an **Exploitation plan**
- **Dissemination actions** performed (3)
- Increase the know-how on the **application of radial basis function mesh morphing** in the medical sector
- Increase the **knowledge on MDT**
- Assess **new HPC cloud-based services** in the medical sector

Final considerations: Benefits of FF4EuroHPC (Social)

- Lowering incidence of **post-surgery complications** and reoccurrence.
- Decreasing days of **hospitalisation**.
- Fast and reliable response (< 48hh) to **support surgery planning** under critical conditions

Final considerations: Lessons learned

- **Deep knowledge** acquired on the use of the **commercial tools** adopted for running Copernicus application
- **Comprehension** of the crucial importance that has the effective strategy to **exploit at best HPC**

Final considerations: Outlook, next Steps

- Assess the feasibility to enable the evaluation of reduced order model **via web**
- Make **less user-dependent** the implemented numerical procedures
- **Disseminate** the implemented numerical procedures concerning Medical Digital Twin
- Search for collaborations with **stakeholders outside consortium**
- Consider the process to get the **certification in the medical field**

Conclusions

- The **Copernicus application** was described detailing the **problem** to tackle, the **procedure** and **numerical means** used
- The strategic advantage of the **HPC usage** was showcased
- The **economical** and **societal advantages** the use of Copernicus application may provide were reported
- The roadmap and rationale of its **exploitation** were outlined

Exp 1006 - Copernicus

Thank you

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