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From HPC to Clinical Practice: Redefining Pre-Operative Planning for Vascular Graft Surgery

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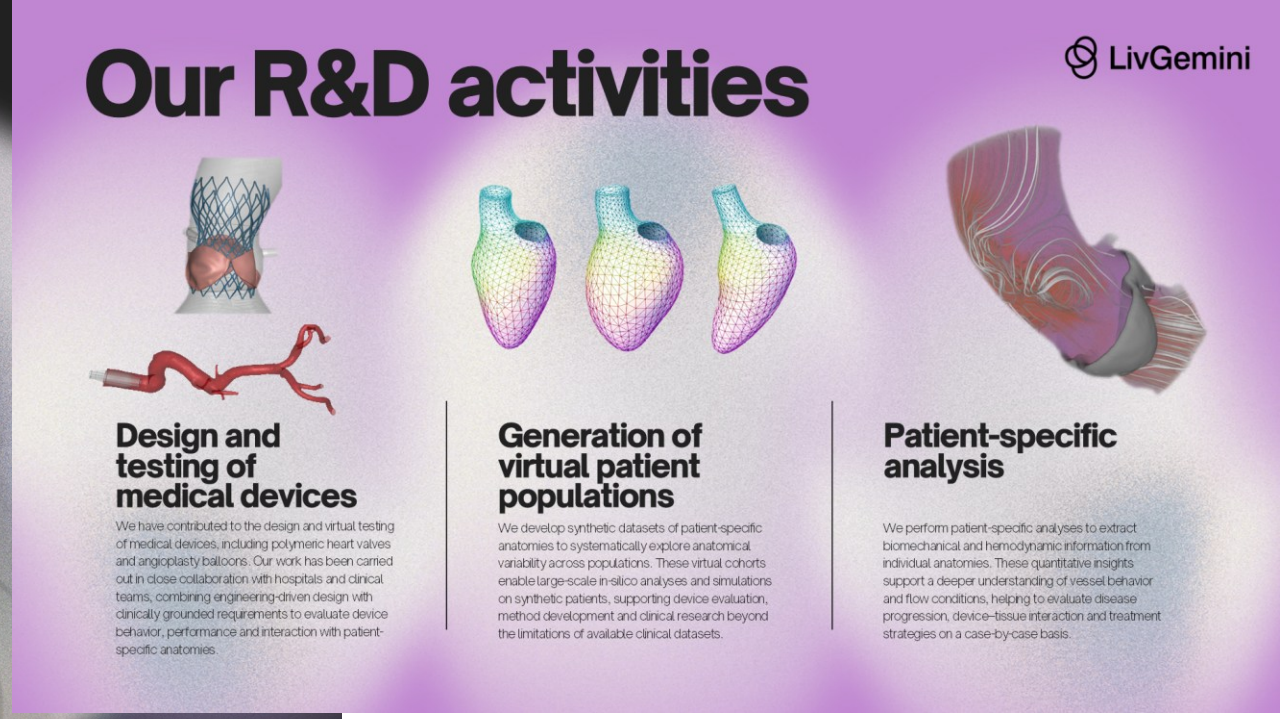
www.ffplus-project.eu

LivGemini

Supporting the clinical decision

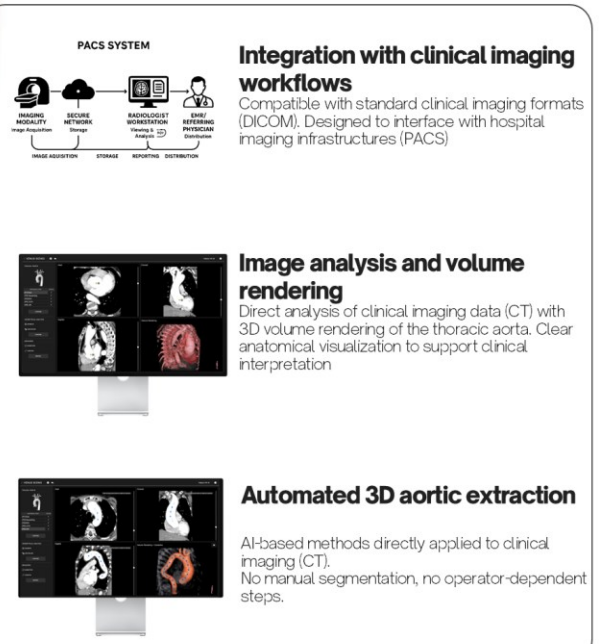
related to Thoracic Aortic Aneurysm

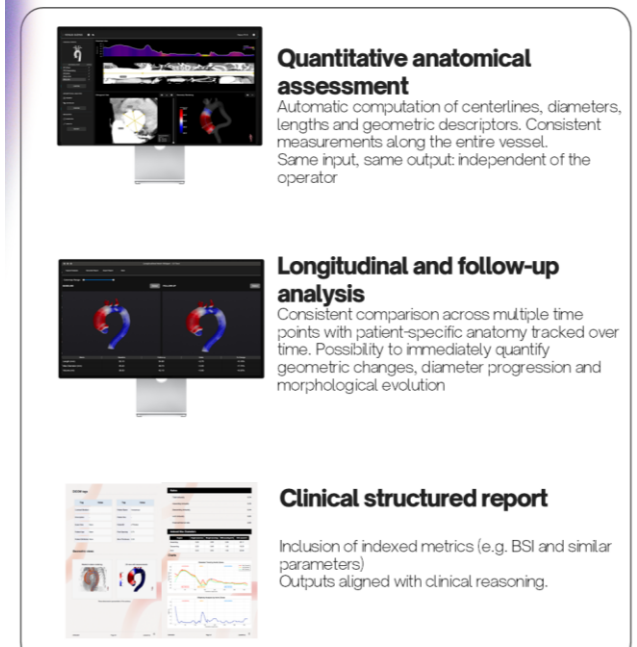


LivGemini

Venus X

Our software product





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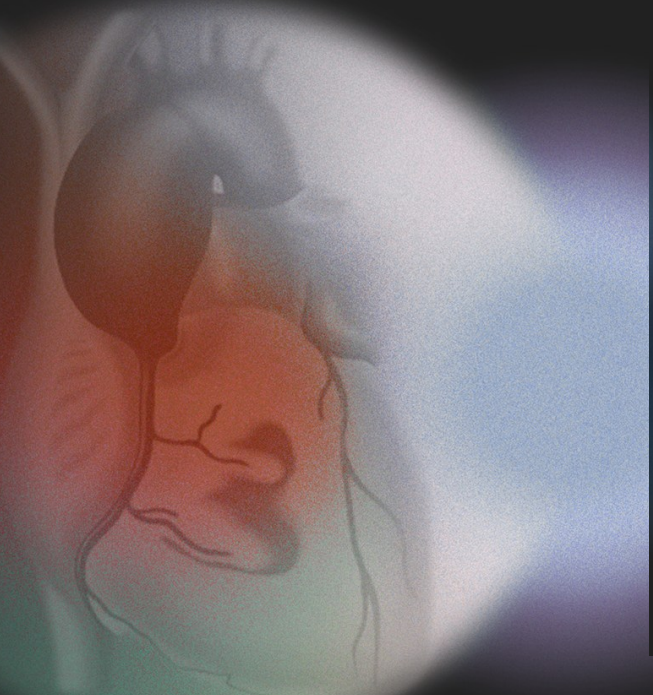
Supporting the clinical decision

related to Thoracic Aortic Aneurysm



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BUSINESS ADVISOR

01 Clinical decision support

The software is designed to support clinical decision-making without replacing the physician's judgment. All outputs are fully transparent and remain under clinician control, with the possibility to review, adjust or override results at any time.

02 Rapid but accurate

The software enables a fully automated workflow from CT images to a structured clinical report in approximately 3 minutes. The process requires no manual processing steps and is designed to fit both routine clinical practice and research workflows.

03 Multi-platform

Available on both Windows and macOS with consistent features and performance across platforms.
Designed for use on standard clinical workstations but also on laptop devices.

04 Data control & Security

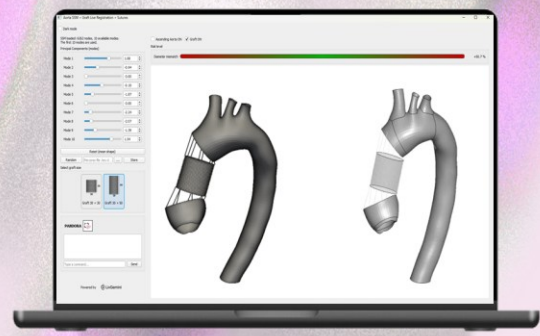
The software runs locally on the clinical workstation/laptop, with no mandatory cloud upload. All patient data remain under full control of the hospital or clinical team, ensuring compatibility with existing data governance and privacy requirements. Full patient management soon available.

Our European projects

PANDORA is a European Union–funded research and innovation project aimed at enabling real-time simulation for medical device testing. The project focuses on simulating the behavior of Dacron vascular grafts to predict kinking phenomena, assess the risk of pseudo-anastomotic aneurysm formation and compare biomechanical responses between straight tube and Cardioroot devices.

Are there patient anatomies for which one graft configuration is mechanically more suitable than another?

Could Dacron graft implantation contribute to increased ventricular workload and long-term ventricular hypertrophy?



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PANDORA

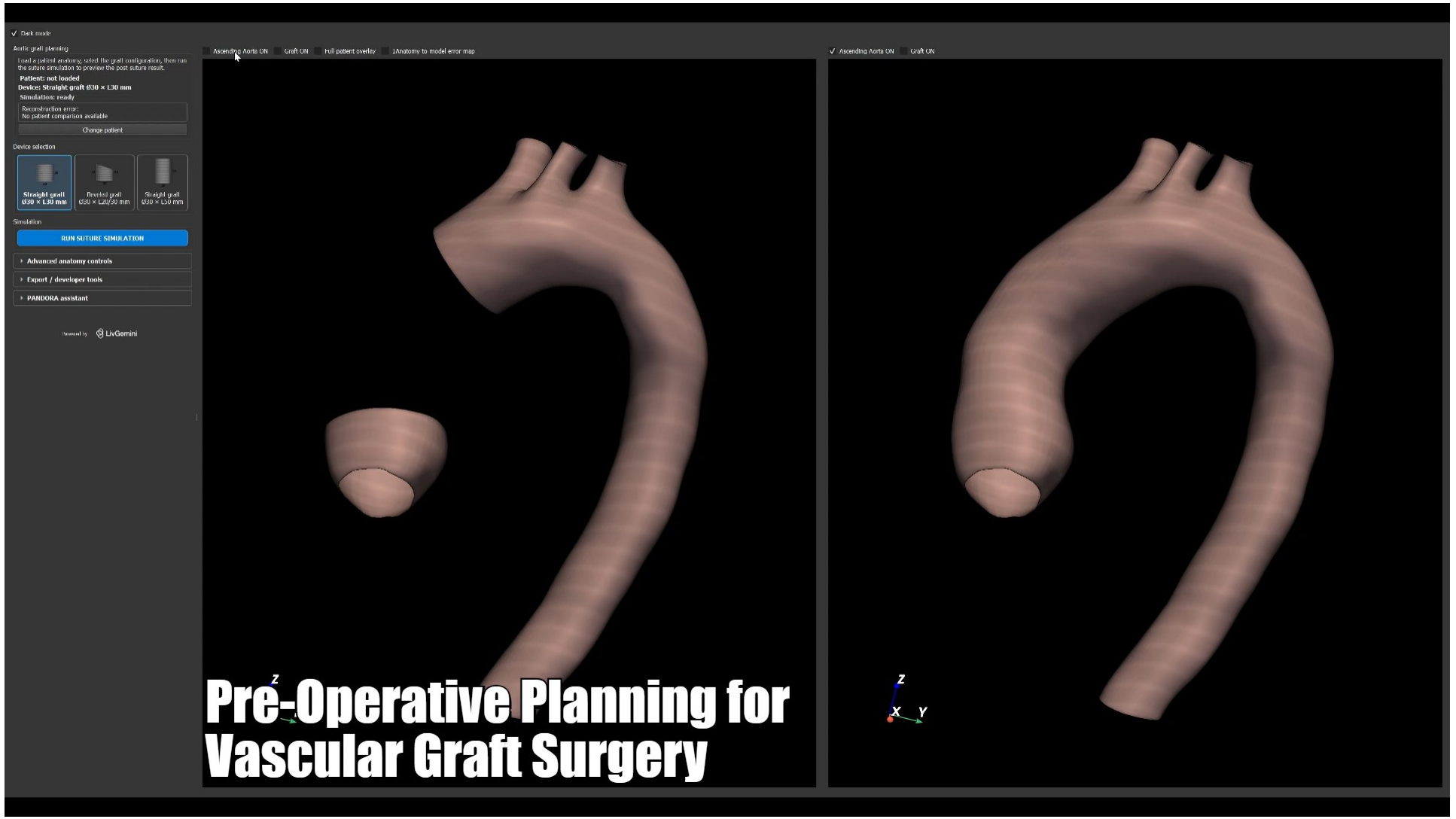
Pre-operative AssistaNt based on Data-driven apprOaches for vasculaR grAft surgery

The challenge

- **The problem**: Aortic graft surgery is highly patient-specific, and approximately **20% of procedures require secondary interventions** due to suboptimal graft adaptation. While **high-fidelity biomechanical simulations** can predict surgical outcomes, they **require hours of computation** and are therefore impractical for routine clinical use.
- **The innovation**: PANDORA combines **HPC, AI, and Digital Twin** technologies to create a pre-operative planning assistant for vascular surgery. Large-scale simulations performed on the Leonardo supercomputer were transformed into reduced-order models and integrated into an **interactive software platform** capable of predicting graft adaptation in near **real time**.
- **Target audience**: The technology benefits **European hospitals**, cardiovascular surgeons, and medical device manufacturers by enabling faster, more informed surgical planning. In the long term, it supports **healthcare providers and patients** through improved clinical outcomes and more efficient use of healthcare resources.

The Solution

https://youtu.be/KlArBykLR-A

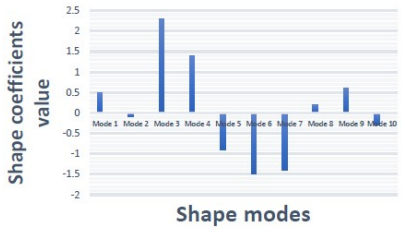


Full pipeline

From 256 design points *per graft* to a real-time surrogate model

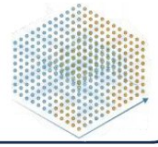
Funded by the European Union

DOE: Design of experiments



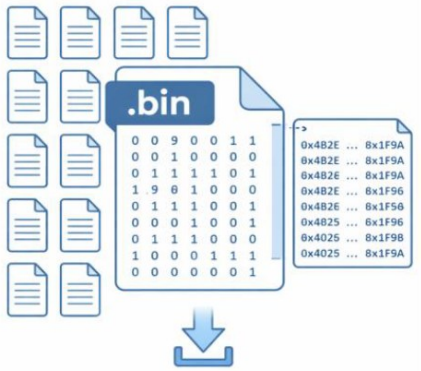
Shape variability: 256 combinations based on 10 shapes coefficients

Latin hypercube (3D approximated representation of a 10-dimension space)

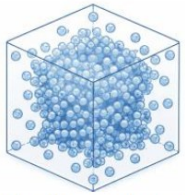


High-fidelity simulations

Snapshot extraction



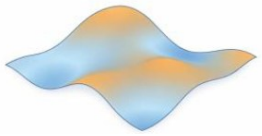
Surrogate model construction



High dimension space

$$POD\colon\ \Phi = U\Sigma V^T$$

GARS: genetic aggregation response surface

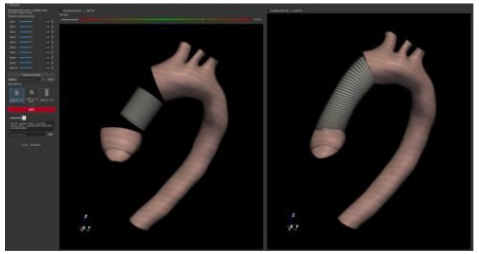


Low dimension space: surrogate model

$$y = f(x) = \sum_{i=1}^{N} \alpha_i \phi_i(x)$$

FMU export and integration

FMU: Final model



LivGemini's application

Computation & Scale

- **73 patient-specific** aortic **anatomies** processed to build a Statistical Shape Model.
- **2000 synthetic anatomies** generated through AI-driven sampling.
- **256 representative anatomies** selected for high-fidelity simulation.
- More than **500 nonlinear LS-DYNA simulations** executed on the Leonardo supercomputer.
- Approximately **900,000 CPU core-hours** consumed during the simulation campaign.

CINECA | HPC
High Performance Computing

Computation & Scale

- How many nodes/GPUs were used?
- By how much did HPC reduce your training/processing time and accelerate commercial deployment?
- Could these computations have been achieved at all without HPC infrastructure?

- LS-DYNA implicit saturates at 8 cores. Our license pool allowed 6 parallel runs.
- We need 256 runs for each variation of the device (just 3 we need at least 30!). Each run takes 3-4 wall clock times.
- Without HPC synthetic dataset generation is not possible.

Configurazione	Real Time (s)	Sim Time (s)	Efficienza (×10−4)	Tempo stimato per 3.5s
8 core	6385	3.500	5.48	1h 46m
12 core	2249	1.119	4.97	1h 57m
16 core	2597	1.300	5.00	1h 56m
20 core	2598	1.205	4.64	2h 06m

```
[sporzian@login02 DOE-2]$ ./succ_rate.sh
==========================================
      Statistiche di Successo DOE
==========================================
Job Processati (Totali) : 256
------------------------------------------
✅ Completati (Normal) : 117 (45.7%)
❌ Falliti    (Error)  : 76 (29.7%)
💀 Uccisi     (Timeout): 63 (24.6%)
▶  In Esecuzione       : 0 (0.0%)
```

CINECA | HPC
High Performance Computing

Impact and European added value

- **Socio-economic Impact**
  - Improved surgical planning and patient outcomes
  - Reduced healthcare costs and re-interventions
  - Strengthens European leadership in Digital Health, AI and Digital Twins
- **Scalability Across Europe**
  - Deployable on standard hospital computers
  - No local HPC infrastructure required
  - Adaptable to different hospitals, devices and healthcare systems

Impact and European added value

HPC Cloud-based additive manufacturing

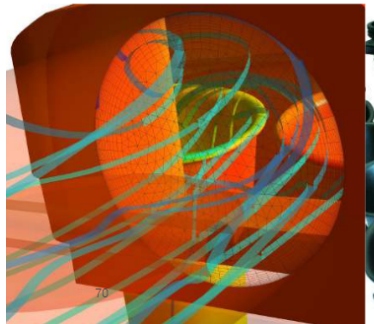
ORGANIZATIONS

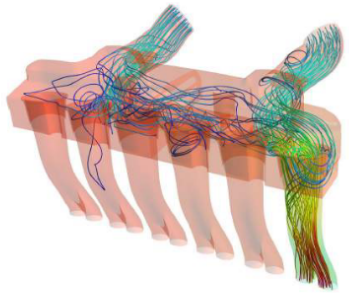
HSL is an SME and a market leader in both Additive Manufacturing and the rapid production of prototypes. In recent years Additive Manufacturing has emerged as a viable mainstream production technology. Overcoming technical and bureaucratic obstacles has allowed 3D printing to grow as a cost-effective option for small and medium scale production together with the ability to produce complex shapes not achievable by standard manufacturing processes. This flexibility in design enables the optimisation of components, a reduction in manufacturing time by almost a third and a halving of production costs by reducing the waste of materials and energy.

End User	Domain Expert	ISV	HPC Provider
www.hsl-italia.it	www.web.uniroma2.it	www.rbf-morph.com	www.cineca.it

THE CHALLENGE

Computer-aided engineering (CAE) tools are able to suggest new shapes and accurately predict the behaviour of components, making them a natural choice in the design chain, but can be prohibitively expensive for SMEs. This is especially true when dealing with complex Computational Fluid Dynamic (CFD) simulations. The goal is to demonstrate the validity of an optimisation service using CAE by optimising a Lamborghini 12-cylinder airbox.





EXPERIMENT #515 HIGHLIGHTS

Industry Sector: **Automotive**

Country: **Italy**

Software used: **RBF Morph**

THE SOLUTION

Numerical grid parameterisation using a mesh morpher avoids the time consuming task of mesh generation (that can take up to 70% of the total analysis cost). Access to CFD simulation through the Fortissimo HPC Cloud allows a speed-up in calculation times reducing the time to market and to return on investment. Using a collaborative, interactive, Cloud interface helps analysts and clients to work together, increasing customer satisfaction and building better products more effectively.

BUSINESS IMPACT

HSL expects that the new service will see the development of a business department with two to three staff, potentially growing to five to six staff after three to four years. For UTV it is estimated that thanks to the new know-how acquired the relevant department will increase its industrial research services. The economic benefit is estimated to be between €40.000 and €70.000 per year in a five-year plan. Finally, this case study comprises a success story for CINECA, in the application field of high fidelity CFD, that is estimated to bring in at least two new SME customers per year, with an approximate 5% increase in revenue for commercial services.

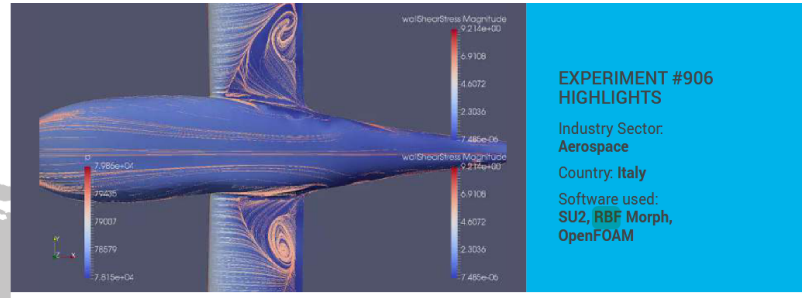
Having access to the RBF Morph morphing tool combined with CFD analysis powered by HPC opens a wide range of business opportunities. In parallel with existing rapid prototyping services, HSL can now propose to its clients alternative component designs corresponding to appropriate performance indicators. For HSL, offering a shape optimisation service in parallel with its existing core business of rapid prototyping activities, represents an opportunity to establish customer activity over a range of key R&D areas. HSL is ready to offer the developed tool to a range of existing clients in the automotive industry, anticipating for the next two years, a total revenue growth of 16% per year in that sector.

BENEFITS

- 5% increase in revenue for commercial service.
- New business service for optimisation of airbox components total revenue growth of 16% per year in that sector.

Impact and European added value

Cross-solver Cloud-based tool for aeronautical FSI applications



EXPERIMENT #906 HIGHLIGHTS

Industry Sector: **Aerospace**

Country: **Italy**

Software used: **SU2, RBF Morph, OpenFOAM**

ORGANIZATIONS

RINA CONSULTING SPA is an Italian engineering consulting company providing high-quality tailored solutions. University of Rome and the National Technical University of Athens provided expertise in numerical optimization and mesh morphing. CNR, the largest public research organization in Italy, provided expertise in cloud technology, with the IAC research group. CINECA is an HPC provider and host centre.

End User	HPC & Application Expert		Application Expert		HPC Provider
www.rina.org	www.cnr.it		www.epu.ntua.gr	www.web.uniroma2.it	www.hpc.cineca.it

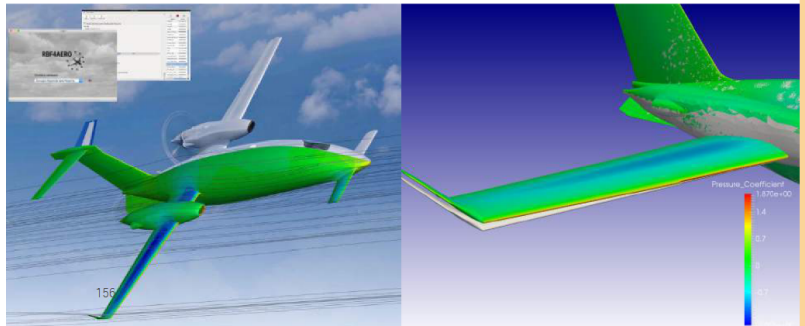
THE SOLUTION

The RBF4AERO platform is a toolbox which tackles all the aspects related to aircraft numerical design and optimization. It does this by making the CFD model parametric through an innovative shape optimization tool based on a high-performance meshless morphing technique.

The experiment performed the successful adaptation of the RBF4AERO platform to work on Cloud-based HPC. This adaptation was applied to the optimization of a component of a real aircraft using computational models relevant to the aeronautical sector. The Consortium benefitted from the technical collaboration with Piaggio Aerospace, which provided the models to set-up the optimization of the shape of the P180 Avanti EVO vehicle.

THE CHALLENGE

For an aircraft production cycle, the ability to reduce production costs decreases rapidly during the first phases of the project. In fact, 80% of the development cost and 70% of the life cycle cost of a product are determined during its conceptual design phase. Considering this, the need to reduce the research and development (R&D) investigation time is significant. Consequently, powerful design tools are essential to shorten the time to acquire physical knowledge about the aircraft components and so to reduce production costs.



BUSINESS IMPACT

Improving aircraft performance has a clear economic value. In this experiment the RBF4AERO platform was used on an industrial case demonstrating its capability to solve a wide range of real world aeronautical aero-elastic optimizations in a reliable and cost-efficient manner. This achievement was realised through the generation of a computational mesh aligned with the requirements dictated by a worldwide mid-size business jets stakeholder, the generation of consistent shape modifications of industrial significance and the demonstration of the feasibility of a fully coupled fluid-structure interaction computation with CAE models characterised by non-matching external surfaces.

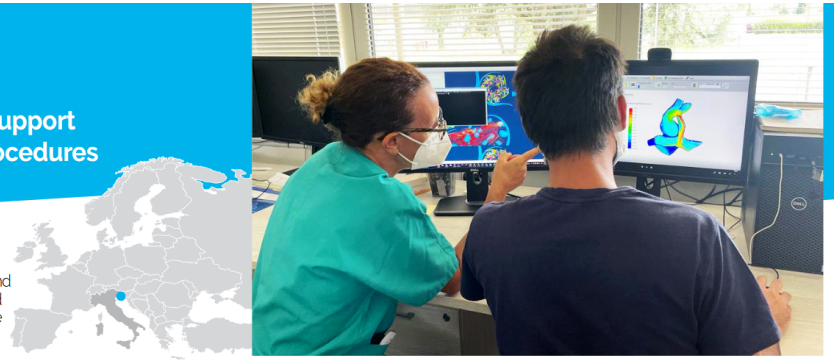
RINA CONSULTING estimates an increased turnover of €100.000 one year after the finalization of the experiment and a total accumulated of at least €400.000 over three years. RINA estimates an increase of at least 2 qualified jobs over three years. The service will allow RINA to lower its current hourly rate by up to 10% and so reach new clients. NTUA estimates an increase by 5% in the revenues coming from FSI related projects in the next three years.

BENEFITS

- RINA CONSULTING estimates an increased turnover of €100.000 one year after the finalization of the experiment.
- The service will allow RINA to lower its current hourly rate by up to 10%.
- NTUA estimates an increase by 5% in the revenues.

Impact and European added value

Cloud-Based HPC Platform to Support Systemic-Pulmonary Shunting Procedures



Industry Sector:
Healthcare
Technology used:
HPC, CFD Simulation

Find out more

Organizations

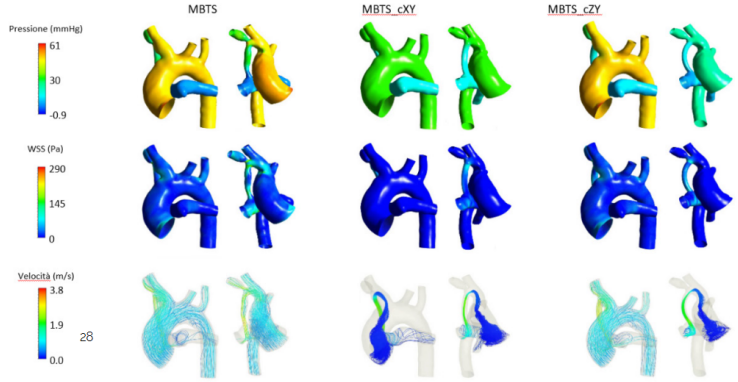
InSilicoTrials Technologies SpA is an SME that promotes innovation and commercializes in silico tools for healthcare through a cloud-based platform. **RBF Morph** is an ISV that develops the RBF Morph software and an expert in CFD and FEA. **Fondazione Toscana Gabriele Monasterio** is a healthcare public entity and a leader in the field of cardiology. **RINA Consulting** provides a wide range of services covering the whole project life cycle, site engineering and maintenance management. **CINECA** is an Italian HPC centre equipped with cutting-edge technology and cooperates with academia and industrial partners.

End User	ISV	Application Expert	Technology Expert	HPC Centre & Provider
InSilicoTrials	rbf	Fondazione Monasterio	RINA	CINECA

CINECA is part of the NCC Italy.

The Challenge

The experiment consortium decided to work in the challenging field of Congenital Heart Disease. Without the ability to alter the prevalence of CHD, interventions and resources must be focused on improving survival and quality of life. In this context, the Modified Blalock Taussig Shunt (mBTS) is the most common palliative operation performed but is associated with significant morbidity and mortality. A simulation of effects could support the medical decision, yet this requires substantial know-how and computing power, in order to provide high-quality results and the subsequent surgery in a short timeframe.



The Solution

The partners generated an affordable decision support web application Copernicus that, thanks to a medical digital twin (MDT), allows surgeons to optimally approach the mBTS medical intervention. Copernicus circumvents problems by generating the MDT through a Reduced Order Model of a patient-specific vascular district, condensing complex computations can be used interactively to vary its dimension and positioning. With a dedicated user interface, the medical staff is thus able to inspect the MDT of the patient and observe how the shunting layout influences the fluid dynamics of the involved impacted area, helping to finalise the decisions on surgical intervention.

The impact of the solution proposed by Copernicus at the clinical level is highly relevant: The combination of speed and interactivity permits surgeons to find the best treatment option for CDT, thus lowering the incidence of post-surgery complications and reoccurrence, leading to a decrease in the days of hospitalisation of treated patients and related costs. For Fondazione Toscana Gabriele Monasterio, this could mean savings in the order of over €100k per year. InSilicoTrials Technologies will add the tool to its portfolio, pursue certification for clinical use, and commercialise it on the market through a SaaS approach, with shares held by RBF Morph and RINA-C, and using CINECA's HPC system as a backend. In addition, both RBF Morph and RINA-C will use the results to increase their presence in the healthcare market: RBF Morph by offering new functionalities in their software library, and RINA-C by offering consulting services backed by hardware and software leasing to medical device manufacturers and medical research clinics.

- IST: Generating an increase in annual revenue of about €450k after 4 years.
- Clinicians: Surgery outcome improved, reducing hospitalization per patient by 5-6 days. FTGM: savings of more than €100k per year are expected.
- RBF: Expected increased annual revenue 4 years after the experiment is €250k, additional 2 qualified jobs/year.
- RINA-C: Expected increased annual revenue 4 years after the experiment is €200k.

Impact and European added value

A Digital Twin for Airflow and Inhaled Drug Delivery in Human Airways

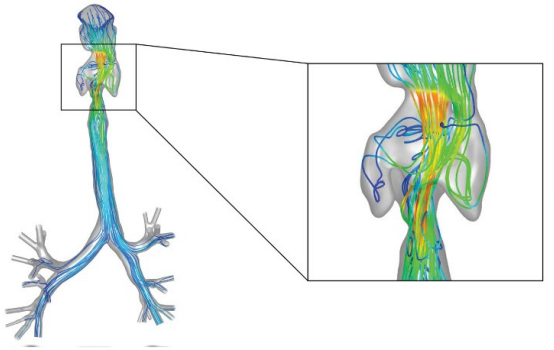
Organizations

One Simulations is a Dutch SME specialised in CFD simulations. **RBF Morph** is an Italian SME developing mesh morphing tools for topology-preserving shape variations. **Grep IT** is a Dutch SME providing technical support in the field of HPC. **Fondazione Toscana Gabriele Monasterio** is an Italian research hospital specialised in cardiovascular and pulmonary pathologies. **TU Delft** is the oldest and largest technical university in The Netherlands.

End User	ISV	Domain Expert	Medical Expert	HPC Provider
one simulations	rbf	TU Delft	Fondazione Monasterio	g/re/p it

The Challenge

Respiratory diseases such as asthma and Chronic Obstructive Pulmonary Disease are caused by local narrowing of the human airways. The efficacy of inhaled drugs crucially depends on drug particle distribution, which is currently assessed by (potentially harmful) inhalation of radio-labelled drugs.
Large-scale CFD particle simulations, such as offered by One Simulations, could be an alternative. Yet, this is time-consuming, error-prone and costly.



Industry Sector:
Healthcare
Technology used:
HPC, CFD Simulation

Find out more

The Solution

The experiment developed a Digital Twin (DT) able to predict the particle deposition of inhaled drugs for individual human airways. It compresses 1000 high-resolution CFD runs on a 960-core HPC system into a Reduced Order Model giving accurate predictions of particle deposition. Clinical users can now simply feed a medical image into the system and tap the canned power of these simulations with a click to optimise the drug particle size without the need for lengthy and costly CFD runs.

The Impact

The created DT is a valuable asset for One Simulations since it can offer an alternative to hospitals for harmful radiative testing and/or expensive and time-consuming CFD simulations, even in emergency situations. Hospitals/clinics can use the solution directly with the consortium operating the DT or by using a licensing structure. Pharmaceutical companies can also benefit from the DT as it can be used to optimize their drug particles or inhalers. The solution will also be offered through consultants who are already selling technical solutions to the healthcare industry, thus easily targeting a large group of customers.
This experiment allows One Simulations to expand into the healthcare industry and to gain valuable experience in creating predictive DT's as the principle can be applied in many other industries.
By deploying this unique tool into the market One Simulations expects to have an increase in 5 high-level jobs and a yearly turnover increase of €1 million within 5 years.

Benefits

- Unique solution offers a practical clinical alternative to harmful radio-labelled drug testing.
- SME expects to create 5 high-level jobs within 5 years.
- SME expects a yearly turnover increase of €1 million within 5 years.

Conclusions

- What has been achieved
  - HPC-enabled generation of a large virtual population of vascular anatomies
  - Deployment of an interactive pre-operative planning assistant for vascular surgery
  - Successful integration of HPC, AI, Reduced Order Models and Digital Twins into a single clinical workflow
- What comes next
  - Validation on larger patient cohorts
  - Extension to additional grafts and surgical procedures
  - Clinical adoption and regulatory pathway
- The Value of PANDORA is the latest step in a journey that includes five HPC-enabled innovation projects developed over the last decade across automotive, aerospace and healthcare.
- Together, these projects demonstrate how European HPC infrastructures can accelerate the transition from advanced simulation to deployable industrial and clinical Digital Twin solutions.

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Thank you!

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https://www.livgemini.com/

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