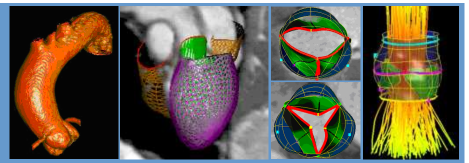
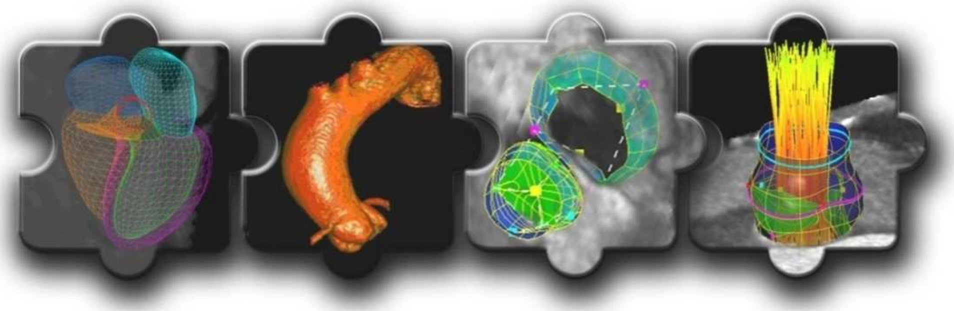
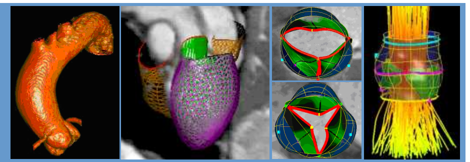


Grid-Enabled Platform for Simulations in Paediatric Cardiology Toward the Personalized Virtual Child Heart

– EU-US eHealth Cooperation Workshop –

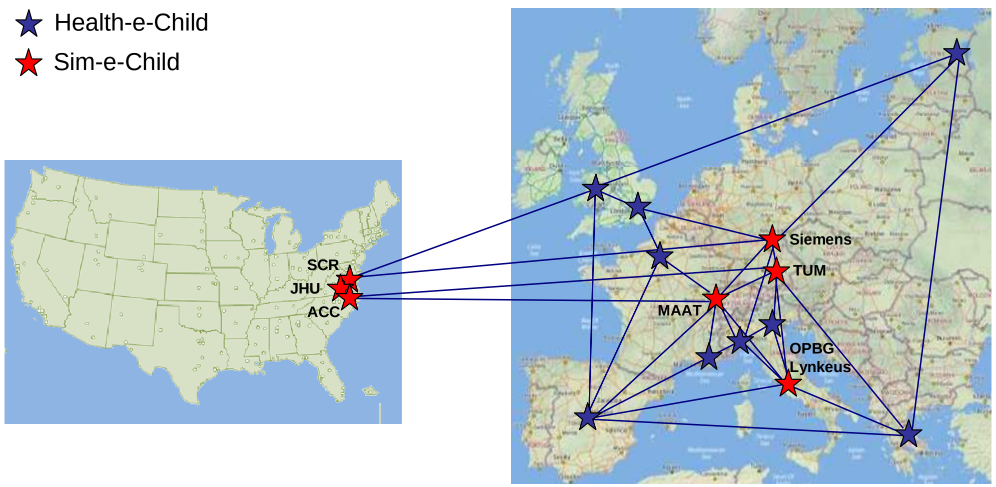
Michael Sühling, Siemens AG





First Trans-Atlantic platform towards personalized & predictive modeling of congenital heart disease

- **FP7 STREP (Follow-up of FP6 Health-e-Child project)** **VPH Initiative**
  - Funding: 1 Mio EUR
  - January 2010 to June 2012
- **International cooperation** between **EU** partners and leading **US** sites



AMERICAN COLLEGE OF CARDIOLOGY FOUNDATION

JOHNS HOPKINS CHILDREN'S CENTER

SIEMENS
Siemens Corporate Research

TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

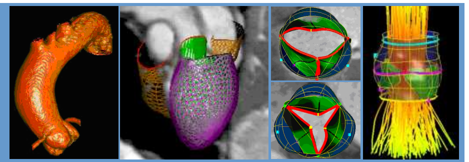
SIEMENS

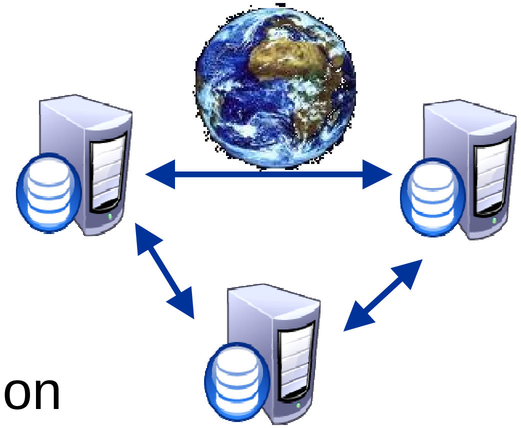
maat

Lynkeus

Ospedale Pediatrico Bambino Gesù
Istituto di Ricovero e Cura a Carattere Scientifico

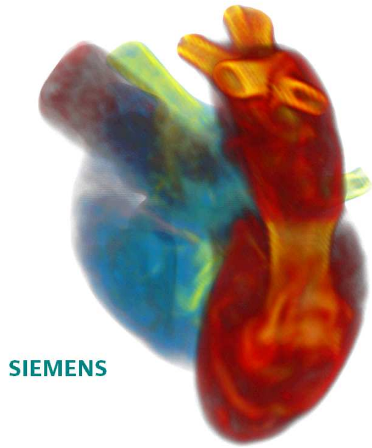
Sim-e-Child: Technical Focus





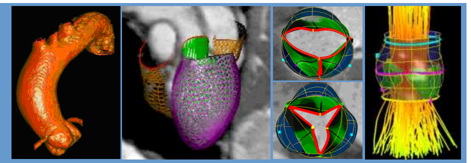
- **Grid/cloud**-enabled **infrastructure** for
  - Aligned clinical databases
  - High-performance computing
  - Information & knowledge exchange

⇨ Enable international, **trans-Atlantic** cooperation



- Computational **modeling** & **simulation** of
  - **Cardio-vascular** anatomy
  - Function
  - **Haemodynamics**

⇨ Incorporate heterogeneous data from **EU** (OPBG) and **US** (COAST)

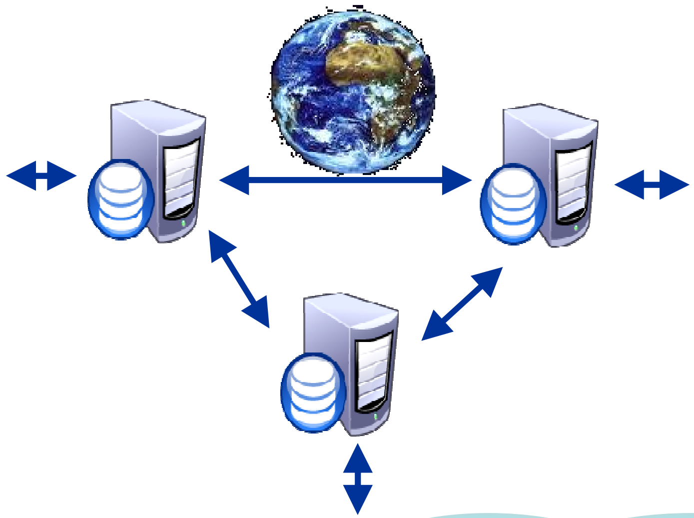


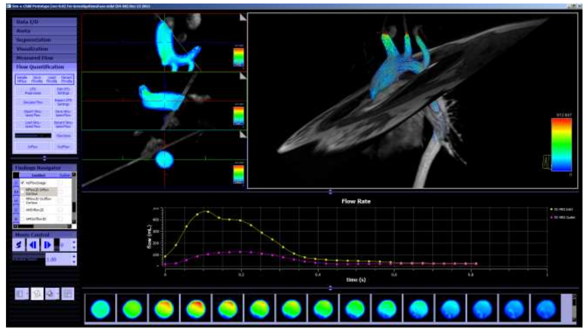
Infrastructure Overview

Web-Portal

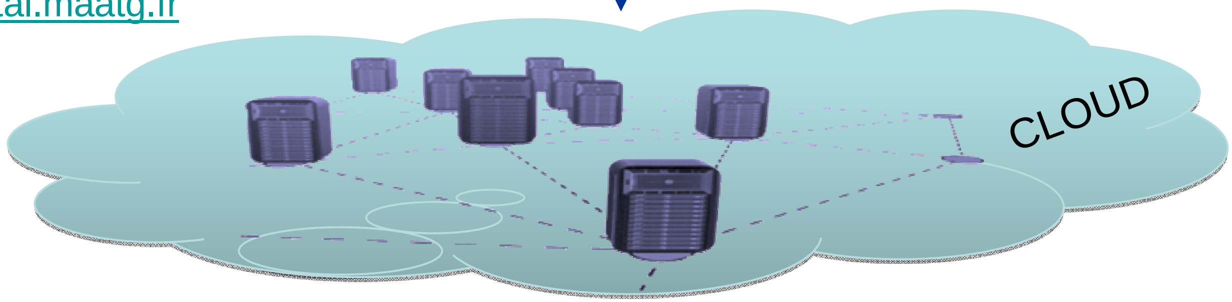
Grid-Enabled, Distributed Data Management & High-Performance Computing

Local SimSys Application in Hospital



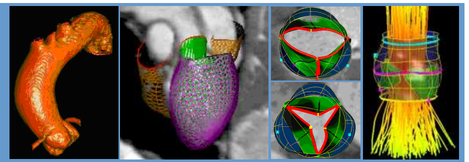


http://sec-portal.maatg.fr

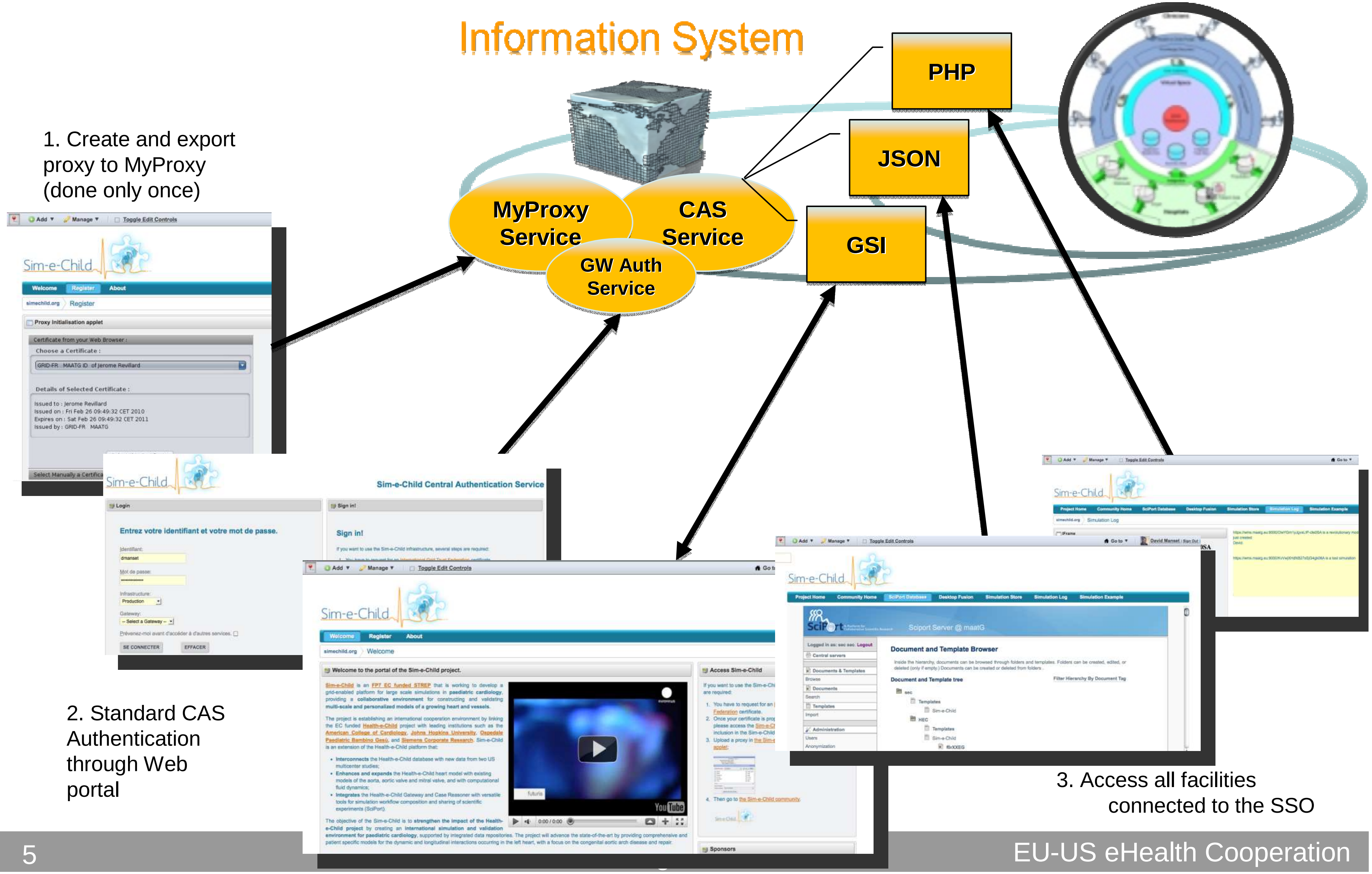


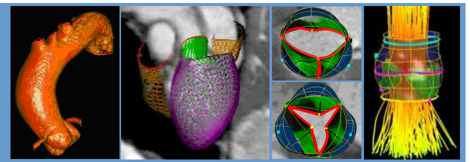
Scalable & **elastic** infrastructure thanks to the Cloud

Infrastructure: Web-Portal



Sim-e-Child

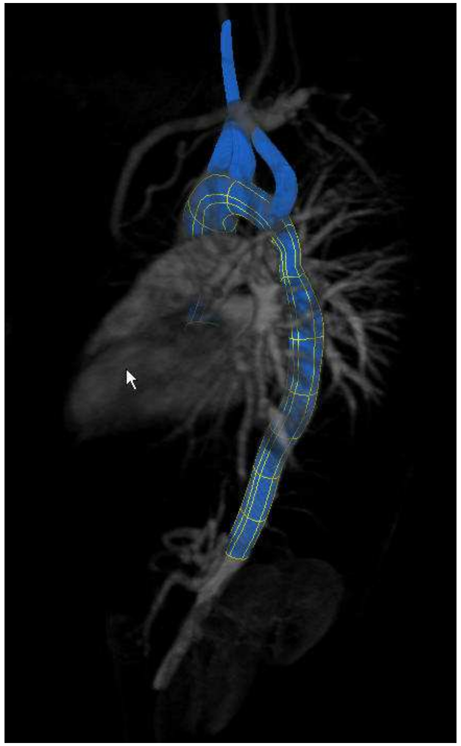


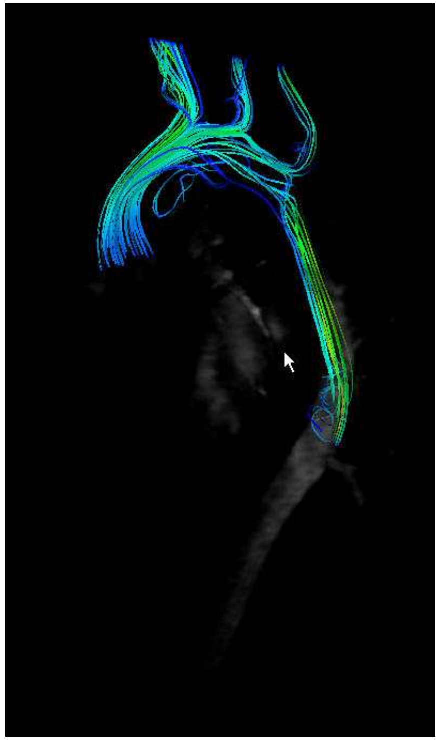


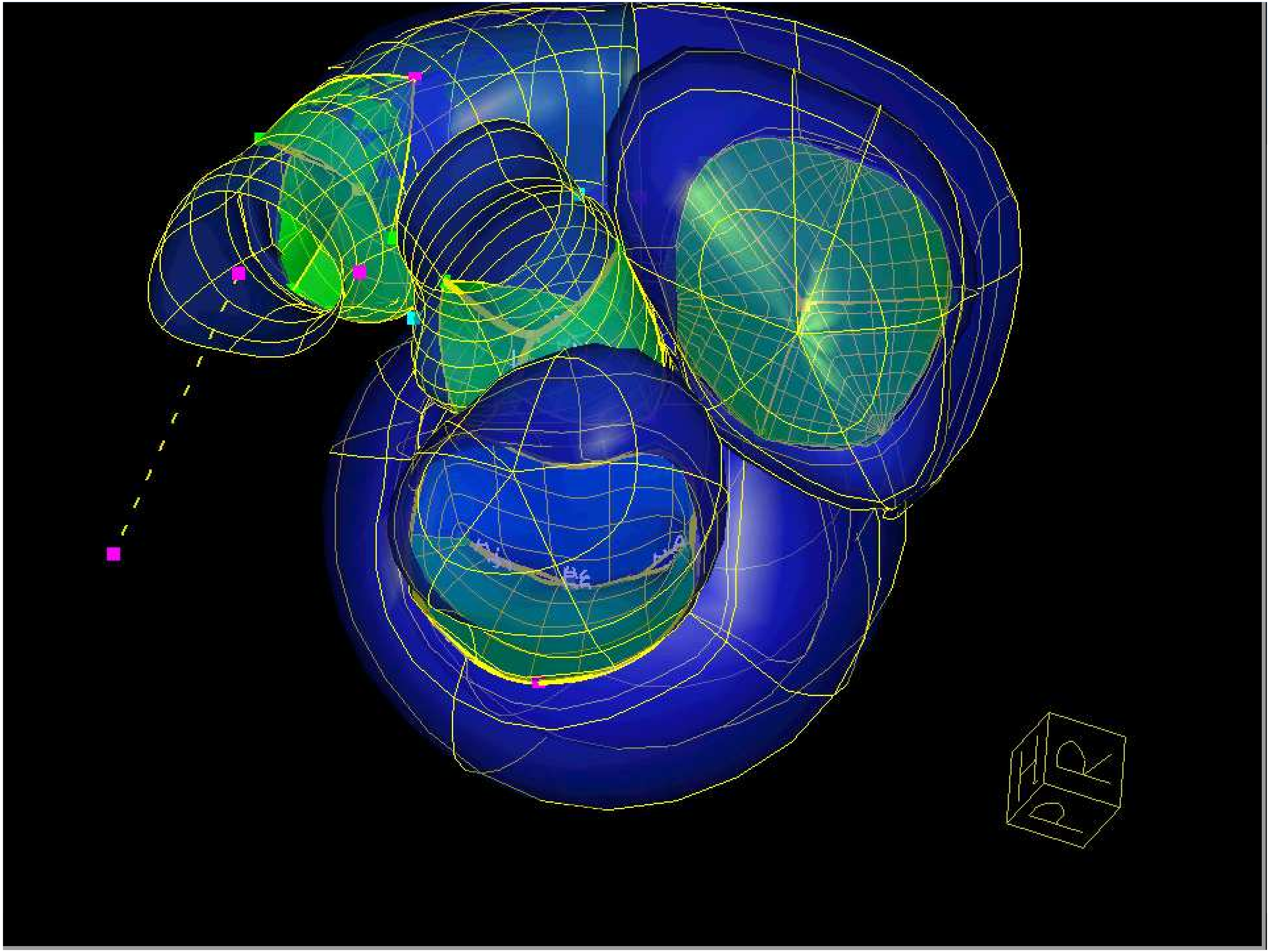
General Modeling Approach

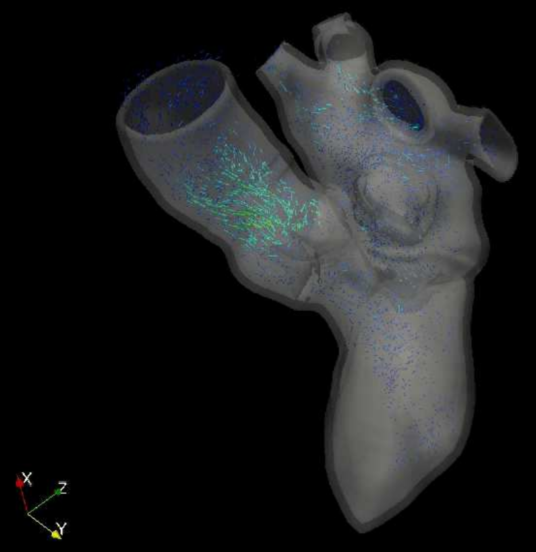
Sim-e-Child

Image Data (MRI) | **Anatomical Model Fitting** | **Haemodynamics Simulation**





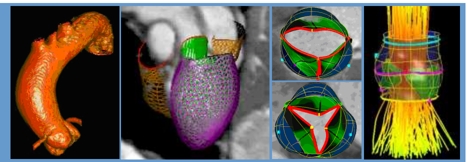




Velocity vectors

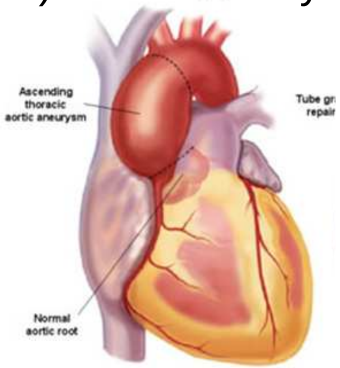
Vorticity magnitude

Sim-e-Child: Clinical Focus



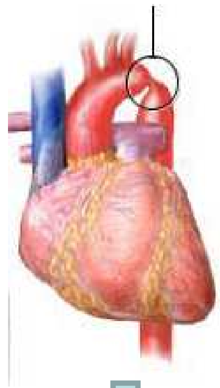
- Model validation: Comparison of models with “ground truth” data
  - Ensure model **robustness** and **reproducibility** on **heterogeneous EU/US** data
- Assessment of **clinical impact** and **benefit**
  - Investigate novel approaches **for planning** & **simulation** of **therapies** to increase their efficacy and safety

1) Aortic Aneurysm



Assess risk of ascending aortic dilation

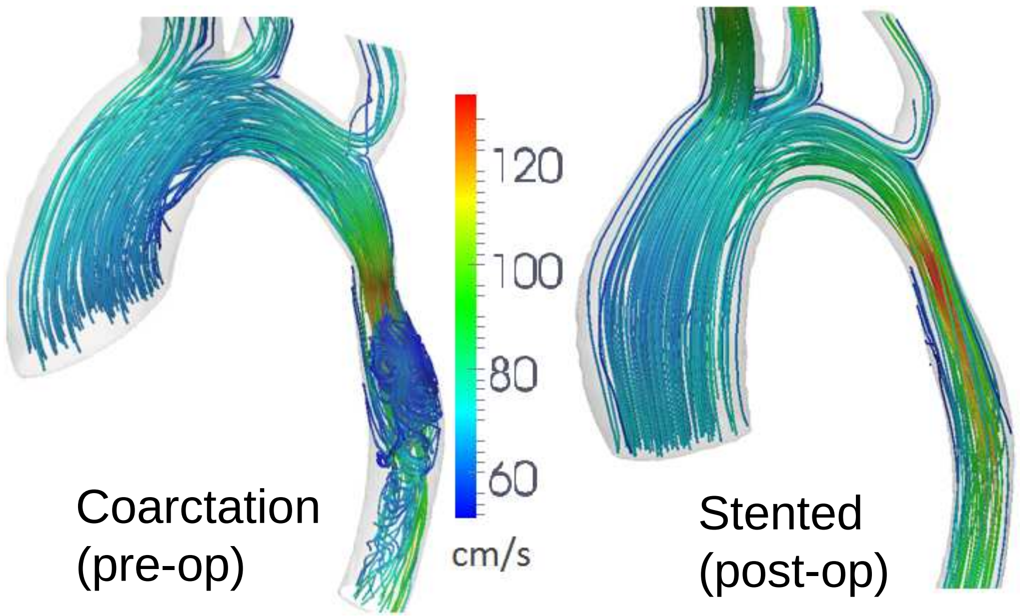
2) Aortic Coarctation



Predict stenting outcome (e.g. pressure gradient changes)

Exemplary Results

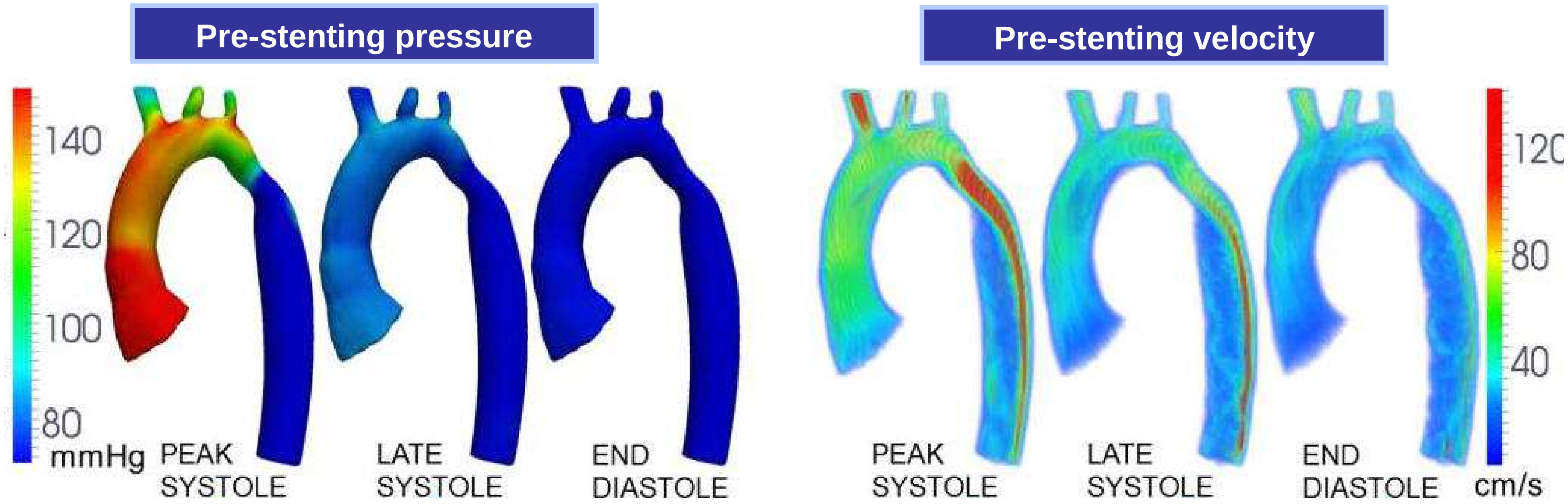
- Pre- and post-operative flow streamlines
  - Pre-op: Complex flow patterns typically associated with stenosis
  - Post-op: After stent implantation, flow is improved, characterized by lack of recirculation



Example of Current Clinical Validation

Sim-e-Child

- Comparison of simulated pressure values with cardiac catheterization pressure measurements in pre- and post stenting cases

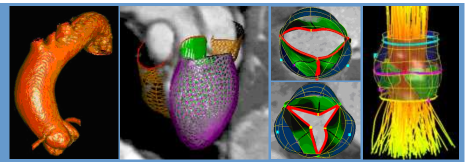


- Next step: Simulate stenting outcome (e.g. changes in pressure gradient) by “inserting a virtual stent” in pre-operative image data

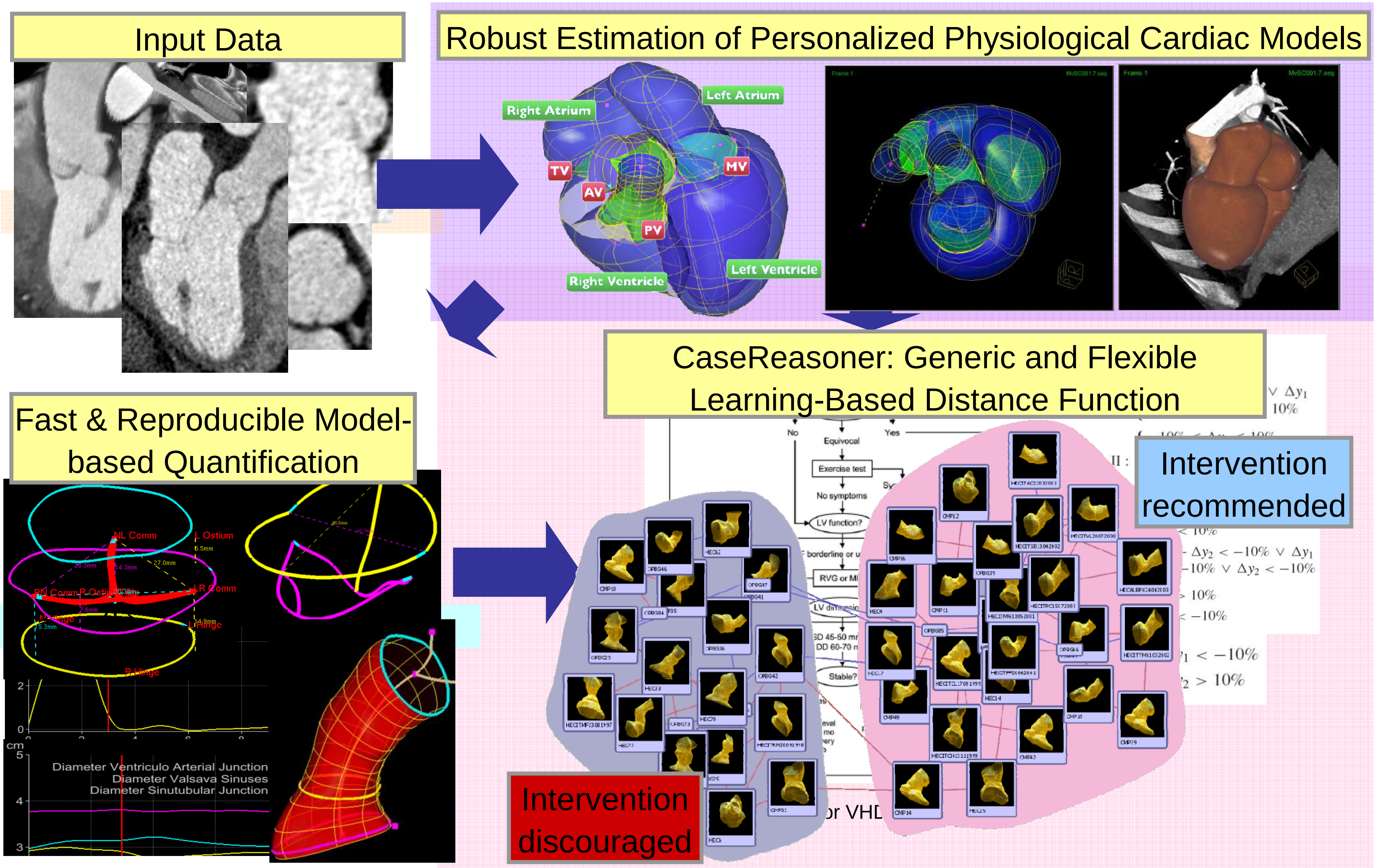
SEVENTH FRAMEWORK PROGRAMME

Information Society Technologies

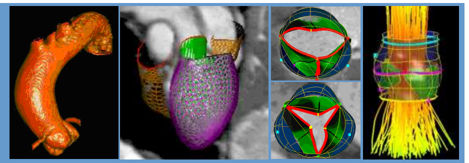
Model-Driven Decision Support

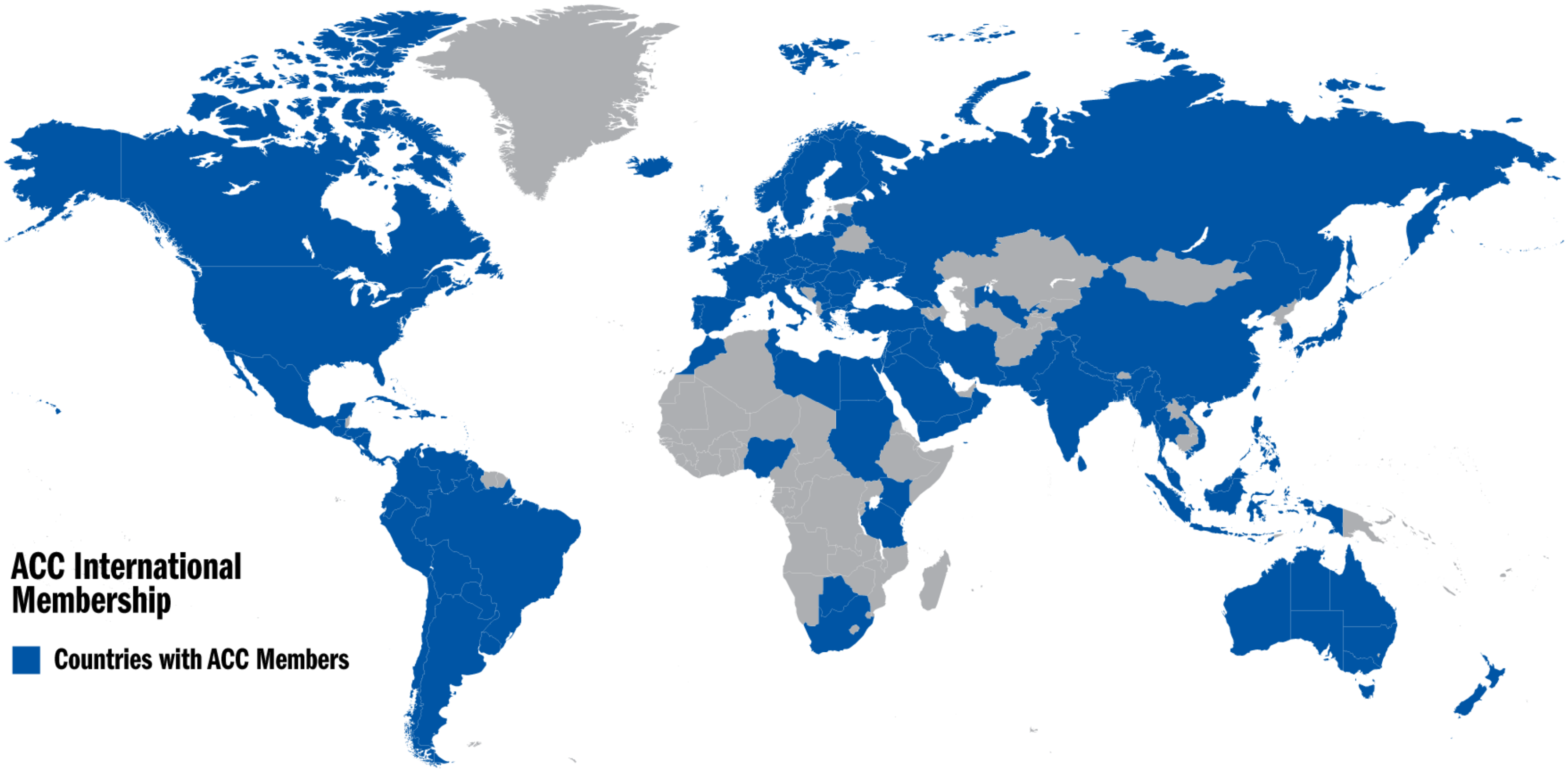


Sim-e-Child

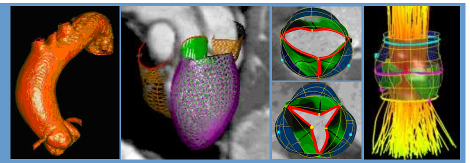


Dissemination & Networking through ACC's Global Network

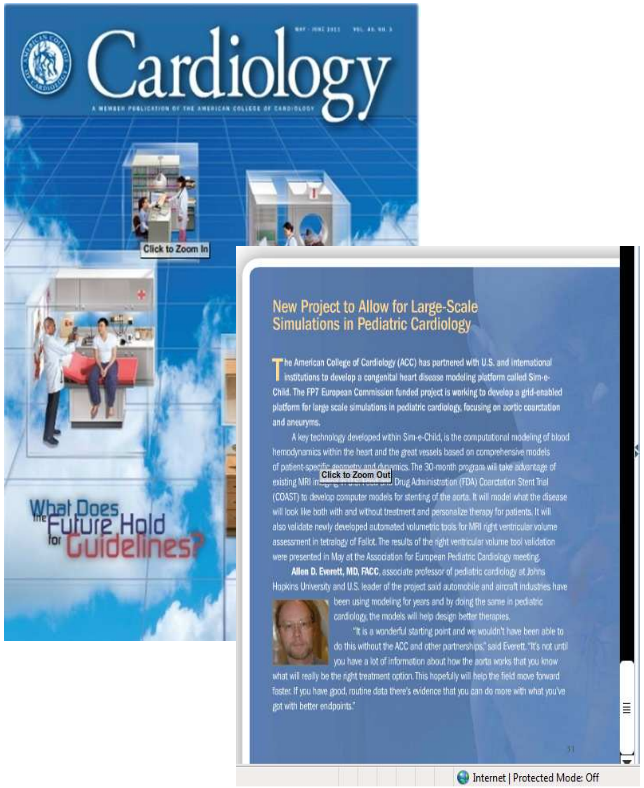




5,000 members in more than 125 countries with ~1000 members in Europe



- Article in Cardiology Magazine – sent to over 40,000 ACC members
- Link to project on ACC's website
- Sim-e-Child booth at ACC.12 (20,000 attendees)
- ACC Heart House Conference planned for June 2012



New Project to Allow for Large-Scale Simulations in Pediatric Cardiology

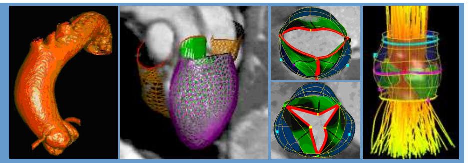
The American College of Cardiology (ACC) has partnered with U.S. and international institutions to develop a congenital heart disease modeling platform called Sim-e-Child. The FP7 European Commission funded project is working to develop a grid-enabled platform for large scale simulations in pediatric cardiology, focusing on aortic coarctation and aneurysms.

A key technology developed within Sim-e-Child, is the computational modeling of blood hemodynamics within the heart and the great vessels based on comprehensive models of patient-specific geometry and dynamics. The 30-month program will take advantage of existing MRI im[illegible] Drug Administration (FDA) Coarctation Stent Trial (COAST) to develop computer models for stenting of the aorta. It will model what the disease will look like both with and without treatment and personalize therapy for patients. It will also validate newly developed automated volumetric tools for MRI right ventricular volume assessment in tetralogy of Fallot. The results of the right ventricular volume tool validation were presented in May at the Association for European Pediatric Cardiology meeting.

Allen D. Everett, MD, FACC, associate professor of pediatric cardiology at Johns Hopkins University and U.S. leader of the project said automobile and aircraft industries have been using modeling for years and by doing the same in pediatric cardiology, the models will help design better therapies.

"It is a wonderful starting point and we wouldn't have been able to do this without the ACC and other partnerships," said Everett. "It's not until you have a lot of information about how the aorta works that you know what will really be the right treatment option. This hopefully will help the field move forward faster. If you have good, routine data there's evidence that you can do more with what you've got with better endpoints."

Benefits of EU/US Sim-e-Child Cooperation

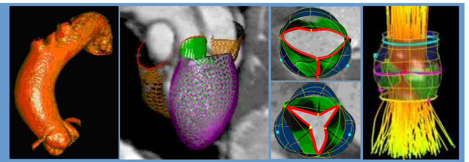


- Base modeling on **broad range** of data (challenge for rare diseases)
  – Ensures more **robust and reproducible models**
- Handle heterogeneous protocols and clinical workflows
  – Increases mutual **interoperability and integrability**
- Increased potential for **dissemination** and **networking**
  – Social networking & community building is **key**
- Exchange of workforces (e.g. PhD student, TUM ⇔ SCR, JHU)
- Increased awareness of different **regulatory processes**
- Leverage **technological & financial synergies**
  – Avoid disparate, redundant work in EU and US

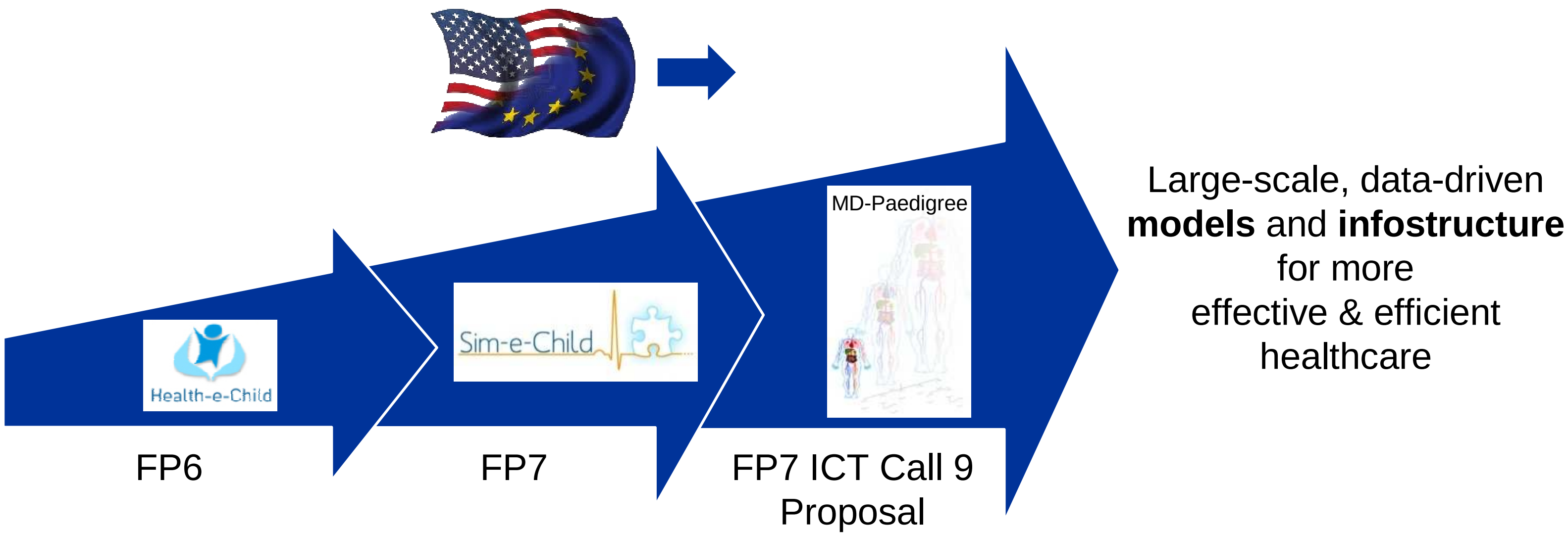
⇩

- Reflects needs of **globally-acting** healthcare industry
  – Penetrate global markets

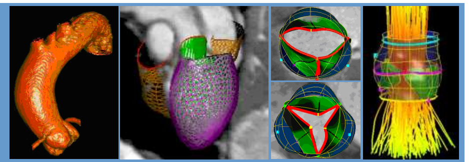
Future Directions & Needs



- **Enhance infrastructure** further to render EU/US international collaboration even more efficient and effective
  - Improve **ease-of-use** and **accessibility**
  - Semantically integrate heterogeneous data
  - Establish **minimal standards** for data and model interoperability
- **Larger data repositories** as basis for modelling
- Extend and **re-use of models across** different **diseases areas**

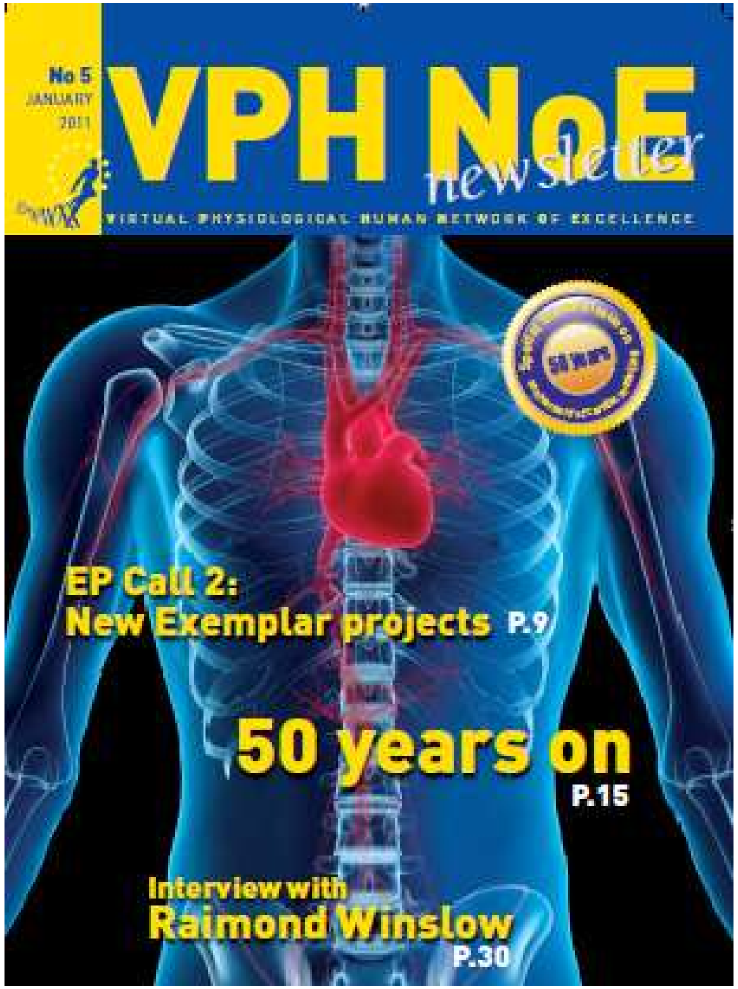


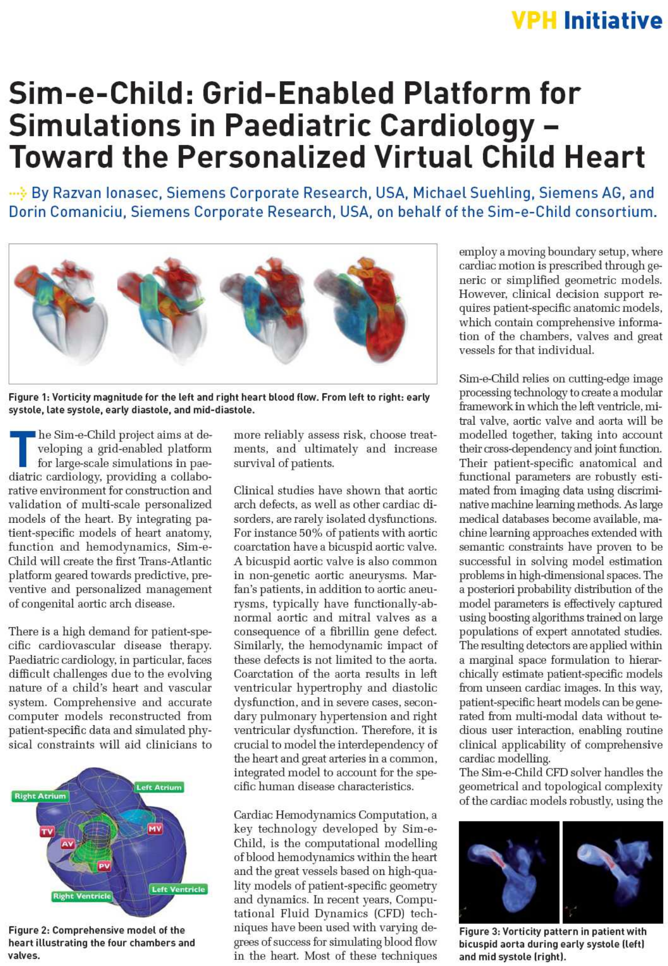
More Information…



Sim-e-Child

www.sim-e-child.org





VPH Initiative

Sim-e-Child: Grid-Enabled Platform for Simulations in Paediatric Cardiology – Toward the Personalized Virtual Child Heart

By Razvan Ionasec, Siemens Corporate Research, USA, Michael Suehling, Siemens AG, and Dorin Comaniciu, Siemens Corporate Research, USA, on behalf of the Sim-e-Child consortium.

Figure 1: Vorticity magnitude for the left and right heart blood flow. From left to right: early systole, late systole, early diastole, and mid-diastole.

The Sim-e-Child project aims at developing a grid-enabled platform for large-scale simulations in paediatric cardiology, providing a collaborative environment for construction and validation of multi-scale personalized models of the heart. By integrating patient-specific models of heart anatomy, function and hemodynamics, Sim-e-Child will create the first Trans-Atlantic platform geared towards predictive, preventive and personalized management of congenital aortic arch disease.

There is a high demand for patient-specific cardiovascular disease therapy. Paediatric cardiology, in particular, faces difficult challenges due to the evolving nature of a child's heart and vascular system. Comprehensive and accurate computer models reconstructed from patient-specific data and simulated physical constraints will aid clinicians to more reliably assess risk, choose treatments, and ultimately and increase survival of patients.

Clinical studies have shown that aortic arch defects, as well as other cardiac disorders, are rarely isolated dysfunctions. For instance 50% of patients with aortic coarctation have a bicuspid aortic valve. A bicuspid aortic valve is also common in non-genetic aortic aneurysms. Marfan's patients, in addition to aortic aneurysms, typically have functionally-abnormal aortic and mitral valves as a consequence of a fibrillin gene defect. Similarly, the hemodynamic impact of these defects is not limited to the aorta. Coarctation of the aorta results in left ventricular hypertrophy and diastolic dysfunction, and in severe cases, secondary pulmonary hypertension and right ventricular dysfunction. Therefore, it is crucial to model the interdependency of the heart and great arteries in a common, integrated model to account for the specific human disease characteristics.

Right Atrium
Left Atrium
TV
MV
AV
PV
Right Ventricle
Left Ventricle

Figure 2: Comprehensive model of the heart illustrating the four chambers and valves.

Cardiac Hemodynamics Computation, a key technology developed by Sim-e-Child, is the computational modelling of blood hemodynamics within the heart and the great vessels based on high-quality models of patient-specific geometry and dynamics. In recent years, Computational Fluid Dynamics (CFD) techniques have been used with varying degrees of success for simulating blood flow in the heart. Most of these techniques employ a moving boundary setup, where cardiac motion is prescribed through generic or simplified geometric models. However, clinical decision support requires patient-specific anatomic models, which contain comprehensive information of the chambers, valves and great vessels for that individual.

Sim-e-Child relies on cutting-edge image processing technology to create a modular framework in which the left ventricle, mitral valve, aortic valve and aorta will be modelled together, taking into account their cross-dependency and joint function. Their patient-specific anatomical and functional parameters are robustly estimated from imaging data using discriminative machine learning methods. As large medical databases become available, machine learning approaches extended with semantic constraints have proven to be successful in solving model estimation problems in high-dimensional spaces. The a posteriori probability distribution of the model parameters is effectively captured using boosting algorithms trained on large populations of expert annotated studies. The resulting detectors are applied within a marginal space formulation to hierarchically estimate patient-specific models from unseen cardiac images. In this way, patient-specific heart models can be generated from multi-modal data without tedious user interaction, enabling routine clinical applicability of comprehensive cardiac modelling.
The Sim-e-Child CFD solver handles the geometrical and topological complexity of the cardiac models robustly, using the

Figure 3: Vorticity pattern in patient with bicuspid aorta during early systole (left) and mid systole (right).