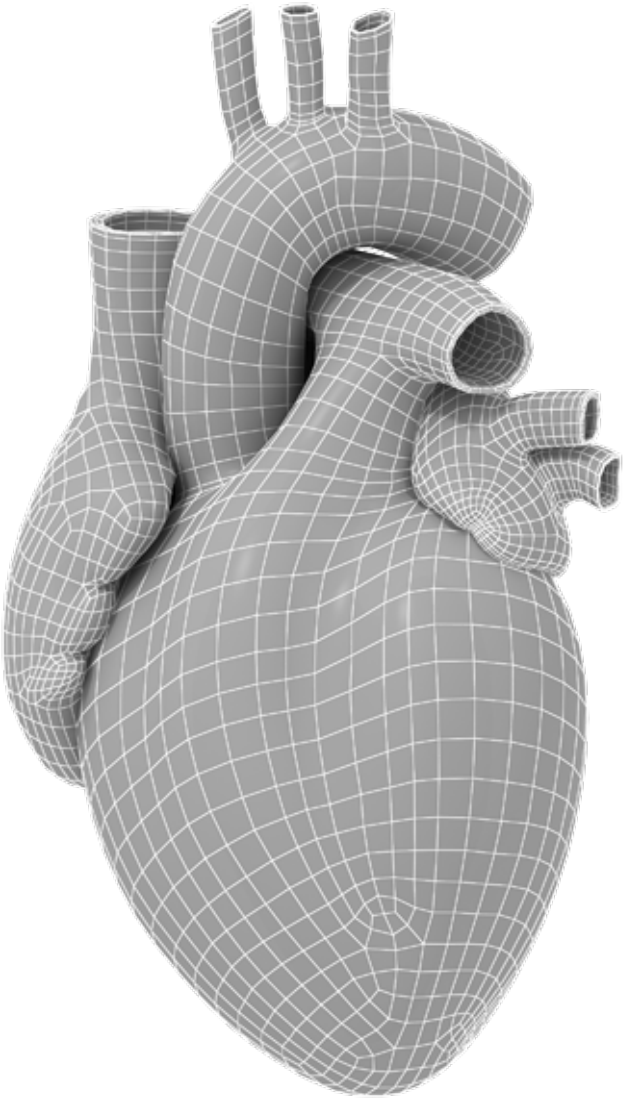
Norwegian Centre of Excellence

Center for Biomedical Computing



Annual report 2008

Words from The Director

While much of 2007 was dominated by our start-up phase as a Center of Excellence, the year of 2008 has allowed most of our team to fully concentrate on their research tasks. The ability to focus the research on a few, large projects requires a smooth organization, which we are very pleased to see that CBC has already achieved. Our projects have clear research plans and goals, combined with very enthusiastic and creative scientists. This has yielded a range of exciting results in 2008 and shows substantial promise for the future.

A couple of activities are still in their start-up phase, and as always when we begin novel research, a period of trial and error is expected before the research gains the expected momentum and quality. We have a long-term perspective on our research and encourage the scientists not to rush for short-term results if these do not contribute to reaching the long-term goals. The research results from our more well established projects, with a history of many years, steadily remind us of the importance of this strategy.

The purpose of this annual report is to show glimpses of both new and more mature activities, along with tabular data of people and production in the center. As the basic organizational and scientific ingredients of CBC were described in the annual report of 2007, we recommend you to read that report before being updated on the news from 2008 in the forthcoming.

The relation between a Center of Excellence and its host institution is of fundamental importance. Our host institution, Simula Research Laboratory, continues to support us in an excellent way with infrastructure, personnel, and strategic advice. Simula reorganized in 2008 and formed three units: one for basic research, one for research education, and one for research applications. CBC works closely with all three units, but most of our activities are related to the basic research and educational units. Having three distinct units in Simula to collaborate with helps making it clearer whether an activity in our center is pure research, has primarily an educational aspect, or constitutes innovation based on research results. We have ambitious goals in all three areas, but also a clear prioritization: research comes before education, which comes before commercial applications. However, the work in the three areas influences each other: recruitment and education of PhD and postdoc candidates are intimately linked to the basic research, and the success of some of the commercial activities now seem to attract external funding to basic research topics in the center.

The research at CBC is organized into seven projects. Three of these projects originate from the Center of Excellence proposal on numerical methods and software for biomedical flows. Two existing Simula projects on numerical methods and software related to biomedical computing were included in CBC already in 2007, as explained in last year's annual report. Two additional projects are new in the CBC context from 2008: Computational Geoscience and Computational Biology. The latter project arose as a result of our goal of recruiting young, internationally recognized researchers to CBC, while the inclusion of Computational Geoscience was decided in 2007. The reason to include this project in a center focusing on biomedical computing is the shared challenges and substantial methodological overlap with respect to mathematical modeling, numerical methods, and software development, as explained more in the annual report from 2007. The inclusion of this activity is also in accordance with the aims of our methods and software having an impact beyond the field of biomedical applications, and in particular on fields relevant to Norwegian industry. Being fully financed by Norway's larges industrial company, StatoilHydro, the research conducted in this project clearly qualifies as relevant. The industry funding and close exposure to a different application enhances our ability to handle a wider aspect of methodological developments and applications of our tools than we otherwise would be able to.

The start-up phase of CBC has seen a strong focus on research collaborations. This focus has been motivated particularly by the interdisciplinary nature of CBC research, which requires close interactions with domain experts. New developments in these external collaborations are described elsewhere in this report. Collaboration is, however, not limited to external partners. Of equal importance is the collaboration between the project groups within CBC. One of our particular strengths is the exchange of personell between projects. For example, some of our project leaders are very active also in other projects and some key senior personell work across several projects. This fact greatly helps to coordinate efforts, improve the flow of information, and focus the research. Many models, numerical methods, and software tools are common among the projects. On the model side, applications primarily deal with electrophysiology, tissue deformation, or fluid flow; finite element methods are dominating on the numerics side; and most projects utilize C++ or Python as programming language, usually in combination with one or more of the software packages Diffpack, FEniCS, PETSc, and Trilinos.

The CBC budget, being almost three times larger than the Center of Excellence grant, now has minor room for futher expansions over the next couple of years. The task of 2009 is therefore to fully concentrate on solving the many hard and comprehensive scientific puzzles that are demanded to reach our ambitious long-term goals.

The CBC management team; (from left) Ola Skavhaug, Bjørn Fredrik Nielsen, Glenn T. Lines, Hans Petter Langtangen, Kent- André Mardal, Anders Logg, Mats G. Larson, and Joakim Sundnes.

Running The Center

While in 2007 the main focus was on expanding the staff and project portfolio of CBC, 2008 has been devoted to consolidating the research projects and new collaborations, and developing further the projects that we have found to have sufficient potential.

Organizational changes

The main organizational changes in 2008 were the inclusion of the two new projects Computational Biology and Computational Geoscience. After this expansion, our project portfolio consists of seven projects:

1) Computational Middleware (CM)
2) Robust Flow Solvers (RFS)
3) Biomedical Flows and Structures (BFS)
4) Cardiac Computations (CC)
5) Inverse Problems (IP)
6) Computational Biology (CB)
7) Computational Geoscience (CG)

Although having separate research focus, goals and plans, there is considerable overlap between these projects, both in terms of related research topics and in key personnel being heavily involved in activities across several projects.

Increased External Collaboration

Efficient collaboration with domain experts is necessary to achieving the goals of CBC. The core of the CBC personnel has their main competence in mathematics and computer science, and it is therefore essential to collaborate with physicists, bioengineers, medical doctors, and geoscientists. However, as all experienced researchers know, effective collaboration is as difficult as it is essential. Through the first two years of operating CBC we have explored a large number of potential collaborations, and are pleased to having established a portfolio of well-working collaborations with excellent biomedical experts. Particular progress in this respect has been made by the BFS project, which has fruitful collaborations with medical professors at the University of Wisconsin, the University Hospital of North Norway, and Oslo University Hospital. These collaborations are viewed as so promising that the BFS project has received a larger portion of CBC's total resources than what was set out in the proposal. The results obtained so far are also far ahead of what was stated in the proposal, with one published paper and more to be submitted to high-ranked medical journals.

In addition to the medical expertise, CBC depends on first class competence on fluid and solid mechanics. Our collaborating groups at the Norwegian University of Science and Technology (NTNU) and the Norwegian Defence Research Establishment (FFI), and their connections to international partners at the Universities of Gent and Cyprus complement the strong in-house knowledge in these fields. Regarding geoscientific applications, the oil company StatoilHydro has proved to be an excellent partner, not only by its highly qualified staff, but also by the company's comprehensive international network of excellent research groups.

The collaboration with FFI is worth mentioning in particular, since this was formally started in 2008. FFI and their partners at the University of Cyprus are experts on computing turbulent flows. Despite the fact that most biomedical flows are laminar, turbulence is thought to be important for some flow phenomena in the cardiovascular and airway systems. For example, inhalation of drugs leads to local turbulence in space and time that significantly influences the transport of the drugs. Turbulent phenomena in bioflows are poorly understood, mainly because they represent a major computational challenge, but CBC's vision is to attack and overcome such computational challenges. We hope to perform some original and useful research in this direction, which can better determine the validity of assuming laminar flow and how to proceed otherwise. More details about these research activities are described later in this report.

People, Recruitment, and Gender Issues

Important recruitments to CBC in 2008 include those of Dr. Kirsten ten Tusscher and the members of her research project: Dr. Molly Maleckar as a postdoctoral fellow and Tim Dorscheit as a PhD student. Increasing the number of women in senior scientific positions is a priority both for CBC and its host institution Simula, and the addition of ten Tusscher to our group of project leaders is very welcome in this respect. One of the positions in her project was funded by a grant from the Research Council of Norway, which was reserved for gender equality measures in the new Centers of Excellence.

Other highlights on the personnel side include the promotion of Xing Cai to full professor of Mathematical Modeling at the Department of Informatics, University of Oslo. Prof. Cai works in a full-time position at CBC, being on leave from the University of Oslo, and is a key player in many of our projects. Another achievement worth mentioning here is that Kent-Andre Mardal qualified for, and was awarded, a permanent research position at Simula. Dr. Mardal is a young and productive researcher spanning almost a continuous set of topics from mathematical analysis via numerical methods and software development to biomedical applications.

CBC and Simula have initiated considerable actions on the issue of equal opportunities in 2008. Most research institutions in information and communication technology have a low number of female employees, and Simula is no exception to this. We are, however, not satisfied with the current situation, and have taken measures to improve. Together with Simula School of Research and Innovation, CBC has had fruitful discussions with Eva Fabry, the Director of the European Centre for Women and Technology (ECWT) and Chair of

the Global Women and Technology (GWT) Network, to explore how we can enhance the recruitment of female researchers on a general basis. We have also invited Senior Lecturer Lina von Sydow from Uppsala University to discuss how to include gender awareness in the courses given by CBC researchers, to render the courses more attractive for female students. This will be important both to broaden the recruitment basis for the courses, and to increase the number of female students in CBC on Master's and PhD level. We were pleased to discover that many of her most important suggestions had already been developed to some extent independently by CBC teachers and incorporated into several of our University courses during the last few years.

In 2008 two committees of relevance for recruitment and gender issues have been established at Simula. One will look into how the gender balance in the institution can be improved, and one will look at possible improvements of how employees from foreign countries and cultures are integrated at Simula. The findings of both these committees will be summarized in a report that will be presented before the summer of 2009.

Scientific Activitities

Most scientific projects have in 2008 continued the established research direction, but some new activities have been started. Below we give an overview of the important activities and results in 2008.

The Research Projects

Computational Middleware

Project leader: Ola Skavhaug

Software is indispensable when using computers to solve mathematical problems. In our and many others' view, the implementation technology for scientific software is developed to considerably less sophistication and maturity than the mathematics and physics of the problems we target. A direct implication of the lack of maturity is that scientific software development consumes large portions of research budgets. Our aim is therefore to improve the implementation technology, especially in the field of software for partial differential equations (PDEs). Through the CM project we try to understand how to construct the next generation software for solving PDEs. The aim is to combine computational efficiency with problem formulation generality and simplicity, in a way that enhances reliability of the computations.

Besides conducting research on these fundamental topics of scientific software, we maintain, develop and distribute several software packages. These serve as test beds and framework for our research investigations, proof-of-concept implementations that demonstrate the applicability of our approaches, and as important stand-alone results that have a potential for substantial impact in the research community. In particular, researchers at CBC now constitute the driving force in the FEniCS project, a collection of software components for finite element solution of PDEs. By using both high-level and compiled programming languages, code generation, and carefully designed middleware interfaces, FEniCS aims to combine the quest for efficiency, generality, simplicity, and reliability. The main effort in the CM project in 2008 has been to prepare the FEniCS software for stable releases. For the FEniCS component DOLFIN this work includes extending the numerical functionality, adding parallel computing support, and making interfaces for several alternative linear algebra backends. Most of our software development is done on the Linux platform, but in 2008 we also started targeting Windows and Macintosh systems.

The distribution of software tools through the FEniCS project was described in the original CBC proposal, and is considered an essential part of our activity. The goal is that our software will help accelerate computational science and engineering elsewhere. However, this is an ambitious goal that requires a strong professional software development attitude. We have therefore created infrastructures for automatic nightly build procedures on many different computing platforms, automatic testing systems, debug tools, revisioning, binary packaging, and email forums for the developers. These infrastructures increase the efficiency of maintaining and deploying public software considerably, but demand significant long-term investments, which would be very difficult to perform without the Center of Excellence grant.

Fundamental research on how to utilize and program future parallel hardware is performed in collaboration with Prof. Scott Baden and PhD student Didem Unat at the University of California at San Diego (UCSD). The goal of the research is to see how FEniCS can be extended to easily deal with the many different upcoming parallel architectures, and achieve high parallel performance, also in demanding, large-scale, multi-physics problems. In 2008 the research has focused on certain key components arising in the solution of sparse systems of linear equations. Didem Unat stayed at Simula for two months in 2008 to understand the opportunities, needs, and constraints of FEniCS regarding parallel computing components.

A new cooperation with Simula's department of Software Engineering started late in 2008, with the purpose of understanding how scientists use and develop software. The research, conducted in close collaboration with Prof. Greg Wilson's group at the University of Toronto, started with a survey gaining almost 2000 responses world wide. Papers summarizing the findings will be written in 2009.

Robust Flow Solvers

Project leader: Anders Logg

The goal of this project is to develop robust and efficient numerical methods and simulation software for fluid flow and fluid-structure interaction. This work includes Navier-Stokes solvers for laminar flow, as well as extensions to turbulent flows. Interaction between bioflows and flexible tissue structures is particularly demanding from

a numerical point of view and requires robust (implicit) coupling of flow and elasticity solvers. The software is based on the components developed by the CM projects, and the resulting robust solvers will serve as key tools for the research in the Biomedical Flows and Structures project. Important ingredients in robust solvers are a posteriori error estimation techniques and adaptive algorithms that automatically tune the local resolution in the individual solvers to achieve overall accuracy.

In 2008, our focus has been on developing the first generation of a software framework for simulation of biomedical flow problems. We have implemented and evaluated a number of commonly used numerical methods for the incompressible Navier-Stokes equations, with a special focus on exploring the efficiency and accuracy of different solution methods. The software programming environment provided by the FEniCS framework has proven to be an essential tool to do this in an efficient and reliable manner. With all methods implemented in the same software framework, we can make more a more objective comparison of methods than when utilizing different software packages. Our plan is not to tie flow simulations to a certain method (which is frequent practice), but to gain experience in choosing the best method for the particular problem at hand. The efforts in developing and testing Navier-Stokes solvers within FEniCS have resulted in a very flexible and easy-to-use flow solver framework that is now emerging to replace commercial packages (like FLUENT and STAR-CD) in the BFS project.

As part of the Outstanding Young Investigator Award (OYI) project Automation of Error Control, we have initiated work on improving the reliability and efficiency of the flow solver framework, based on computing reliable error bounds and adaptive mesh refinement in space and time. We are also targeting large deformation fluid-structure interaction in complex geometries. During the year, we have begun exploring the use of Nitsche's method for weakly imposed continuity on composite meshes. This allows the use of separate meshes for fluid and structure, which enables large relative deformations between fluid and structure. To handle formulations on composite meshes, we have implemented efficient algorithms for computing intersections between arbitrary overlapping meshes in FEniCS. We have also worked on proving a posteriori error bounds for splitting methods and made initial progress on a general methodology for automated derivation of error bounds. During 2009, we hope to develop this methodology further to simulate blood flow through the aortic valve and extend FEniCS with functionality for automated error control.

The work on the reduced basis element method for hierarchical flow systems continued with a particular focus on rigorous a posteriori error estimators with the same low computational order as the method itself. In addition, the basic ingredients of the method have been added to an existing software library, LifeV, making testing of full 3D viscous flow problems possible. For the moment only stationary problems on non-coupled domains have been tested, but the LifeV software library opens up possibilities to work with also time-dependent problems and fluid-structure interaction problems.
To strengthen our competence on fluid mechanics, and in particular to extend the general flow solver framework to also include turbulent flow, we have initiated a collaboration with research groups at the Norwegian Defence Research Establishment (FFI) and the University of Cyprus. The first steps in our collaboration focus on exchanging competence, extending the flow solver framework to include turbulent flow, and verifying implementations. This work started in 2008 and will continue with higher intensity in 2009. Further research activities in the FFI group are described as part of the Featured Research section.

Biomedical Flows and Structures

Project leader: Kent-André Mardal

The purpose of the BFS project is to apply the numerical methods and software developed in the CM and RFS projects in a few selected, important applications that have the potential for making an impact on clinical medicine or on fundamental medical understanding. When planning and writing the proposal for a CoE, biomedical flows and structures constituted a completely new area for the researchers at Simula. Consequently, the short-term goals listed in the CBC proposal were modest. However, an activity on flow simulations in cerebral aneurysms was started when writing the proposal, and during the first two years of CBC, we have been particularly eager at accelerating the research in this project. By means of some very fruitful collaborations and excited project workers at CBC, our current research achievements have proceeded far beyond the initial plans.

Clinicians are seemingly excited about the usefulness of our computational fluid dynamics (CFD) research. We have been invited to give presentations in medical communities three times this year, both in Norway and the United States. Communicating across different disciplines, such as mathematical modeling and medicine, is demanding and time consuming. Fortunately, the clinicians demonstrate both excitement and patience when explaining their clinical challenges. Both parties realize that it is indeed a long-term effort to bring flow simulations to a stage where the clinical benefits are obvious and widely accepted.

We have in 2008 worked closely with the CM and RFS projects to develop flow software within the FEniCS project, and to streamline the work-flow from biomedical image data to flow simulations, by using the Vascular Modeling ToolKit (VMTK). This work has been done in close collaboration with Luca Antiga, the developer of VMTK, and enables biomedical image data in DICOM format from, for example, MRI scans into FEniCS via VMTK. This has greatly enhanced the efficiency of conducting patient-specific blood flow simulations.

Three main biomedical applications have been addressed in 2008. The first concerns simulations of blood flow in cerebral aneurysms, which is done in close collaboration with Prof. Tor Ingebrigtsen and Jørgen Isaksen at the University Hospital of North Norway. We have submitted one paper on a clinically motivated study concerning the amount of coil filing in aneurysms and its effect on the blood flow and resulting shear stress in the vessel walls. Together with Isaksen and Ingebrigtsen we obtained funding through the NevroNor program

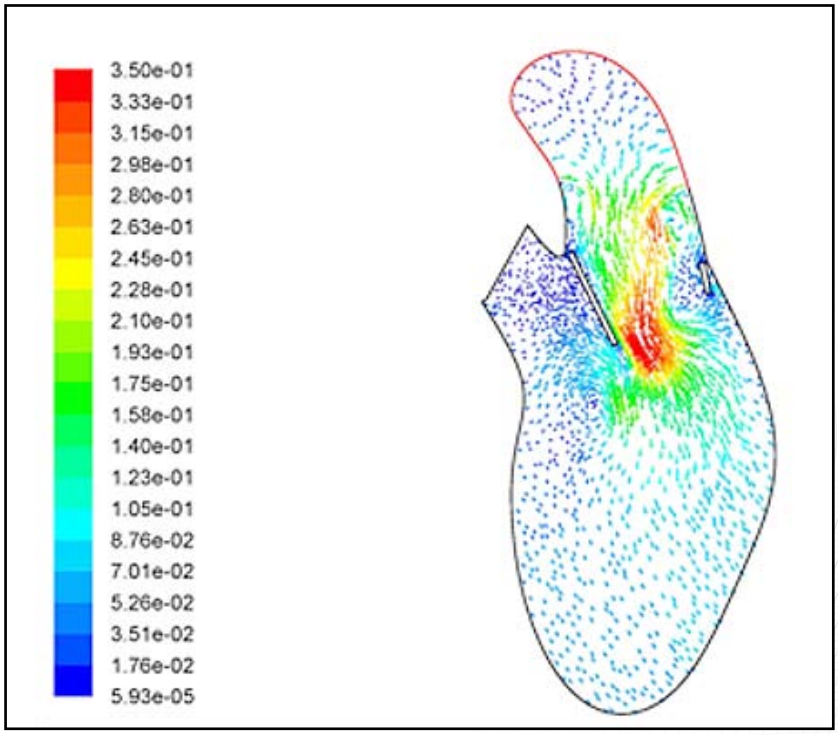
for the project Development of New Technology for Improving Risk Assessment of Intra-Cranial Aneurysms Using Computer Simulation Models. A related project in this area was started in 2008, as a joint project with Charles Strother, who is Professor of Neuroradiology at the University of Wisconsin. Together with Prof. Strothers' co-workers Jiang Jingfeng and Wieben Oliver, at the Department of Medical Physics at the same university, we aim at validating the blood flow simulations against novel 4D phase-contrast MR measurements in canine subjects. By doing a thorough validation of our computational models, we hope to be able to convince more clinicians that CFD simulations can provide accurate and valuable information on flow patterns in aneurysms and the surrounding blood vessels.

The second application is the flow of the water-like cerebrospinal fluid (CSF) in the cranio-cervical region and its association with the development of cysts within the spinal coord (syringomelia). Such cysts are often found in patients with the Chiari I malformation, which is characterized by a downward displacement of the brain such that the CSF flow is obstructed. Medical researchers believe that the resulting abnormal flow pattern may be a cause for syringomelia. By using flow simulations we are computing the flow characteristics and the stress that acts on the spinal cord, in idealized anatomies, to investigate the effect of flow obstructions. This work is in close collaboration with Prof. Victor Haughton at the medical faculty, University of Wisconsin (Madison, USA).

The third application concerns modeling the behavior of the mitral valve in the heart. Understanding the mechanics of the mitral valve and its coupling to the blood flow is important for improving valve replacements. So far, this work, carried out at the CBC node at NTNU, has mainly concentrated on modeling the (anisotropic) tissue of the mitral valve and its movement due to prescribed forces. Extensions to fluid-structure simulations of the valve's interaction with the flow of blood are now in focus. This is a very challenging problem requiring deep insight in biomechanics and numerical methods. This research is conducted in collaboration with Prof. Jan Vierendeels at Gent University in Belgium.

The primary achievement of the biomechanics group at NTNU the last year was the PhD thesis *Modelling and Numerical Analysis of the Porcine and Human Mitral Apparatus*, which was defended in October 2008 by Victorian Prot, who now is continuing the research in the center as a postdoctoral fellow. In the thesis, he implemented an incompressible hyperelastic transversely isotropic constitutive model, for solid finite element analysis of mitral valves. The model was used to investigate the influence of the collagen structure of the mitral leaflets on mitral valve response with different layer arrangements. This study suggests an important finding, namely that the material heterogeneity employed does not influence the global response of the mitral valve. Further, he found that with the current constitutive model, the valve bulges too much in the left atrium compared with ultrasound recordings.

The biomechanics group also works on implicit fluid-structure interaction (FSI) algorithms for biomechanics applications, in collaboration with Prof. Jan Vierendeels (Gent University, Belgium). The Tango framework, developed by Prof. Vierendeels, for coupling FLUENT and ABAQUS is being explored for implementing the FSI solvers. For example, successful simulations of opening and closure rigid mitral leaflets have been performed (in 2D), with a patient-specific rendering of the left atrium and the left ventricle (see figure). This work will hopefully be extended to clinical applications, presumably bilealfet mechanical heart valves (BMHV).



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Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=4,2960e-01)
FLUENT 6.3 (2d, dp, pbns, dynamesh, lam, unsteady)

Cardiac Computations

Project leader: Glenn Terje Lines

In the Cardiac Computations project we develop computer models of electrophysiological and mechanical aspects of the heart, and use these models to study selected biomedical applications. To perform accurate computer simulations of a beating heart, a detailed, complex mathematical model is needed, which gives rise to a series of challenges. From a theoretical point of view it is interesting to derive properties of the solutions. To solve this problem on a computer one needs stable and fast numerical methods. Finally, there are challenges related to how such a complex system can be implemented in software in an efficient yet flexible way. In the project we have addressed all these topics, along with more application-oriented problems.

The CC project has traditionally had a strong focus on the computational aspects of the problem, i.e., to develop efficient and reliable numerical methods for solving the involved equations. This work has continued in 2008, especially focusing on improved solvers for mathematical models of cardiac cells, in addition to the writing of a comprehensive review paper that summarizes recent developments in computational methods for simulating cardiac electrophysiology.

On the application side there has been a focus on automatic cells, i.e., cells that activate and contract spontaneously. The activation and contraction of the cells is normally triggered by external stimuli, but cells may activate spontaneously during various pathological conditions. This spontaneous activity may either propagate onto neighbouring cells and trigger an extra heartbeat, or just be suppressed by neighbouring normal tissue. The outcome depends on a number of factors, such as the volume of the self-depolarising cells, the degree of automaticity of these cells, and the conductive properties of the surrounding tissue. We have studied the stability of these heterogeneous systems with eigenvalue analysis and have derived quantitative conditions for extra (ectopic) heartbeats. In a related line of work, we have studied arrhythmias in relation to ischemic heart disease. It is known that arrhythmic episodes, such as ventricular fibrillation, occur more frequently during the acute phase of ischemia. Using a simplified model we were able to reproduce the characteristic rise and fall in the probability of arrhythmia during the first half hour after onset of ischemia.

Anti-arrhythmic drugs have been shown to increase mortality in patients suffering from myocardial infarction, thus highlighting the need for better drugs. We have approached this challenge as an optimization problem where a prospective drug is characterized by a set of parameters. The cost function essentially rewards restoring normal cell function, and penalizes side-effects. The approach has shown promise in using mathematical models for virtually testing out the effect of drugs.

Inverse Problems

Project leader: Bjørn Fredrik Nielsen

In the Inverse Problems project we investigate, in collaboration with Rikshospitalet HF, possibilities for improving the ECG technology. Our main efforts are concerned with ischemic heart disease, which is a reversible precursor of heart infarction. Instead of employing the standard methods of contemporary medical research, we develop mathematical models and software for analyzing ECG recordings and thereby identify whether a patient suffer from this disease. Moreover, our technology also provides an estimate for the position and size of the lesion/injury such that appropriate medical care can be performed. In view of the number of people suffering from this disease, this is certainly a very important problem.

In 2008 we tested our methods on a number of patients at Rikshospitalet HF. The results are promising, but many challenging unexplored issues must be investigated in order to validate the potential benefits of the system. In addition, the theoretical aspects of the problem were further explored. The main result of these efforts may be summarized as follows. The challenge of identifying the ischemic region may conveniently be split into two subtasks: the computation of the potential at the heart surface from ECG measurements, and the computation of the shift in the transmembrane potential, i.e., the ischemic region, from the heart surface voltage distribution determined in first subtask. The first subtask can be regarded as the classical Cauchy problem for an elliptic partial differential equation and is well-known to be severely ill-posed. We have proven that the second subtask is a stable problem, but does not have a unique solution, i.e., further apriori information must be invoked.

Computational Biology

Project leader: Kirsten ten Tusscher

This project focuses on two distinct areas in computational biology: the dynamics of evolutionary processes and the mechanisms of cardiac arrhythmias. Arrythmias also constitute a topic in the Cardiac Computations project, but with a much stronger focus on developing models and computational methods, while the present project has its main focus on the biological and medical consequences.

The dynamics of evolutionary processes

The goal of the evolutionary dynamics activity is to study questions from two main areas of evolutionary biology, speciation and development. For speciation the question is how a single biological specie may give rise to multiple species, given that sexual reproduction by exchanging genetic material tends to damp arising differences. For development the question is how a single fertilized egg cell gives rise to a multicellular body consisting of a large range of specialized cell types at specialized locations, despite that all these cells contain the same set of DNA instructions.

Classically, highly simplified evolutionary models have been used, which severely restricts the potential routes for evolution. In the present project we aim at using stochastic agent based models to

simulate evolving populations. We study how more realistic models can help shed light on long-standing evolutionary questions. Because of the size and complexity of these models, part of the effort will be on efficient numerical techniques, algorithms, and parallelization.

In 2008 we wrote an article demonstrating that speciation is less difficult than shown by classical models when using our more realistic modeling approach. This research will be extended by a new PhD student in 2009. Furthermore, the first steps have been taken to establish contacts and possibly a collaboration with another Center of Excellence, the Centre for Ecological and Evolutionary Synthesis (CEES), led by Prof. Nils Stenseth at the University of Oslo.

The dynamics and mechanisms of cardiac arrhythmias

The aim of this part of the project is to elucidate mechanisms behind cardiac arrhythmias which may contribute to improving medical prevention and intervention techniques.

Our research will focus on the role of two factors influencing arrhythmias: intracellular calcium dynamics and fibrosis (connective tissue formation). Both of these topics have over recent years received considerable attention for their potential role in arrhythmogenesis. Despite the importance of arrythmias, the mechanisms are poorly understood. In 2008 we also wrote a paper on the characteristics of ventricular fibrillation in the human heart. We have started to incorporate more detailed calcium dynamics in the human cardiac cell model to study the role of calcium in arrhythmogenesis. Furthermore, we have started a joint activity with the CC project on the role of certain mutations in arrhythmias and how to help clinicians measure the seriousness of the condition of these patients. In addition, we aim to study the role of fibroblast cells and their electrical properties, extracellular matrix proteins, and different architectures of fibrosis (diffuse, patchy, stringy) in arrhythmogenesis. A new postdoctoral researcher was recently employed to take on this research. For this project we plan to use in-house software, which will be further developed in collaboration with the CM project.

CBC is greateful for the additional funding of this project that was granted by the Research Council of Norway in 2008.

Computational Geoscience

Project leader: Are Magnus Bruaset

The activities in computational geology and geophysics were included in CBC from 2008, but the project dates back to 2005 when Simula and StatoilHydro agreed to build a strong and long-term research collaboration. The main goal for this collaboration is to strengthen the procedures in oil and gas exploration through new and improved computer-based models of geological and geophysical processes. The challenges in mathematical modeling, numerical methods, and scientific software development in this project are shared with those of the other CBC projects. Having the project as a part of CBC makes it easier to exploit the similarities and ensure a mutual benefit of methodological advances in geoscience and biomedicine.

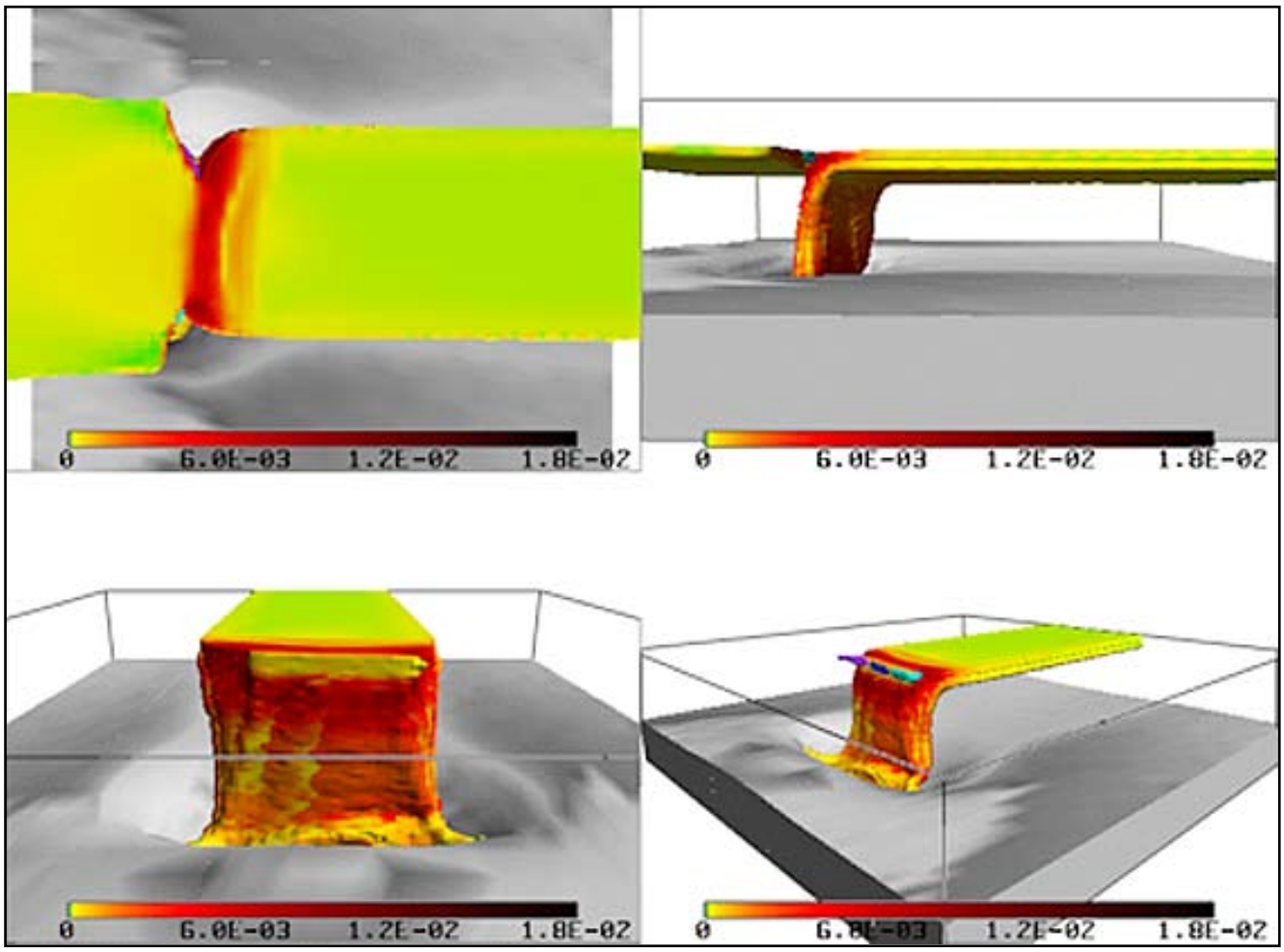
The computational geoscience project is fully funded by StatoilHydro and consists of two parts, one development part carried out by the commercial company Kalkulo, and one basic research part performed within CBC. Kalkulo is a wholly owned subsidiary of Simula. So far, Kalkulo has developed two important technologies and corresponding software tools for use among geoscientists in StatoilHydro. A very interesting feature is that the tools and their use demand a need for new fundamental insight, which now appears to give rise to new basic research projects. The intimate connection between basic research in CBC, development in Kalkulo, and applications in StatoilHydro has proved to be strategic for identifying important future research problems.

The basic research tasks within CBC regard four topics: improved reliability of depositional models for the geological evolution of sedimentary basins, better insight in the physics of sediment transport, simulation of mantle dynamics coupled to plate tectonics, and improved parallel computational tools for accurate descriptions of local deformations in sedimentary basins.

A particular focus in 2008 has been on calibration and quality assessment of depositional models. In terms of calibration, model parameters governing the diffusion of sediments in a water-filled basin are computed such that they match values of layer thickness and rock composition in observable wells. The applied methodology is based on experience that has been developed in the Inverse Problems project for automated detection of heart failures from ECG measurements. Although recent scientific literature states that solving inverse problems arising from depositional models is computationally infeasible, our results indicate that certain inversion strategies will indeed work.

Ongoing research also looks at deposition of sediments as a stochastic process. Using the so-called probabilistic collocation method, it is possible to compute expectation and variance of PDE models with assumed probability distributions for the model parameters. This is a novel combination of a new application field and an existing methodology, which is believed to improve the quality assurance of depositional models. Until now, the results from traditional models of deposition have been met with skepticism due to the large level of uncertainty present in the input parameters. The recently developed

procedures may estimate the corresponding uncertainty in simulation results, which is of fundamental importance for the success of computational tools in oil exploration. There is a similar uncertainty problem in many parts of biomedical computing, and the methods developed in the Computational Geoscience project are likely to have novel applications and significant practical value in biomedicine too.



Using numerical models, researchers at Simula probe the forces governing the movement of tectonic plates at subduction zones. Each of the panes represent different views of a subducting plate, top views are to the left, perspective views to the centre and side views to the right.

Promising results are also emerging from work in progress on a new approach to simulation of mixtures of water and sand, which is a fundamental problem of sedimentation. The computational tools are here based on Lattice Boltzmann methods and a hybrid particle-continuum approach to transport. These methods also have a potential for bioflows (for example, a collaborating group at the University of Erlangen, Germany, applies Lattice Boltzmann methods to blood flow).

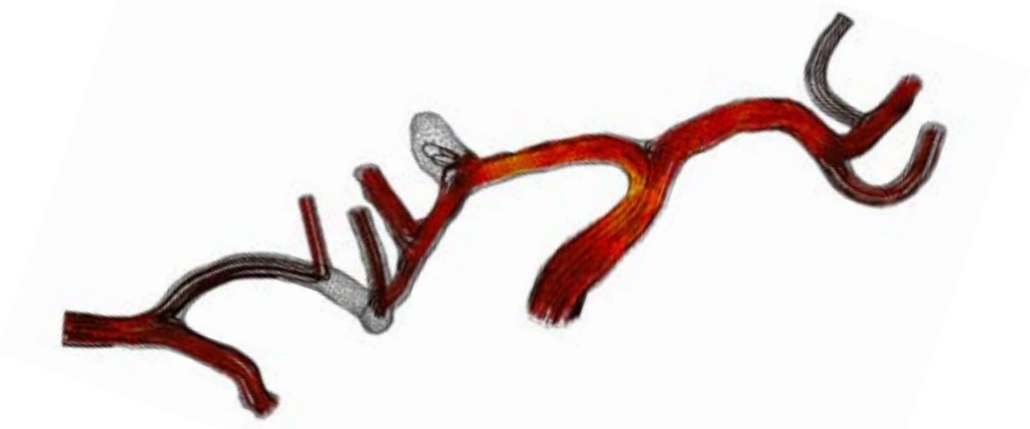
Another research task concerns parallel solution of three-dimensional models for fluid flow, heat transfer, and elastic deformations in sedimentary basins. The challenge is to develop the right methods that achieve the expected parallel efficiency also on large computers with thousands of computing nodes. Only widely applicable numerical methods and implementations are in focus, as the resulting software must handle a wide range of different geological scenarios. Therefore, progress in this direction is likely to be of benefit also to other simulation codes at CBC, for instance that of simulating the electrical activity in the heart.

A particularly interesting development, coming up next year, is basic research related to a software tool developed by Kalkulo, the so-called Litosphere Model. This is a model for the geological evolution of the earth. In collaboration with top international groups and Statoil-Hydro, we will study various mantle flow problems using real data from the Litosphere Model.

Featured Research 2008: Blood Flow in Cerebral Aneurysms

Stroke is one of the leading causes of death and disability in the western world. It is estimated that 1-7% of all strokes are caused by subarachnoid hemorrhage (a bleeding into the subarachnoid space that sourrounds the brain), which is usually a consequence of the rupture of an aneurysm. Around 1-6% of the general population develop aneurysms during a life-time. These aneurysms are easily identified using CT or MR angiograms. However, the anual risk of rupture when having an aneurysm is low. It is generally estimated to less than 1%. Therefore, neurosurgeons face a difficult dilema: many have aneurysms, but relatively few of these aneurysms rupture. The consequence of rupture is, however, often fatal. In addition, treatment of aneurysms, which is usually done either by clipping (clamping of the aneurysms) or coiling (filling the aneurysm with platinum thread), are difficult and risky procedures. The clinicians are therefore eagerly searching for new methods to assess the risk of rupture as precisely as possible. Today's risk indicators are usually based on epidemiology studies, and are difficult to apply to individual patients.

Aneurysms typically develop within or around the so-called Circle of Willis, which is a network of blood vessels at the base of the brain. It is well known that the anatomy of this network of vessels varies considerably from person to person. Our hypothesis is that these anatomical differences cause variations in the blood flow distribution, and that these variations may lead to abnormal stress distribution in the vessel wall. This hypothesis, which is sound from a fluid dynamics perspective, is supported, and in fact originally suggested, by our collaborating clinical researcher Prof. Tor Ingebrigtsen at the University Hospital of North Norway in Tromsø.



Blood flow simulation in a patient specific geometry with an aneurysm.

Together with Prof. Tor Ingebrigtsen, his PhD student Jørgen Isaksen, and some of their collaborating neurosurgeons, we published a paper in the prestigious medical journal Stroke in 2007, where we demonstrated that CFD computations on the complete Circle of Willis is indeed feasible on serial computers. Furthermore, we studied the effect of altering the radii, angles, and outflow conditions on the pressure and shear stress distribution at the vessel walls. In 2008, we have continued our collaboration with Ingebrigtsen and Isaksen and have submitted a paper on a clinically motivated study concerning the amount of coil filling in aneurysms. The background for this study is that there is currently a debate among clinicians whether treatment of aneurysms is best done by surgical clipping or endovascular coiling. Clipping usually eliminates the danger of aneurysm rupture and re-growth, but is a difficult procedure. Coiling is less invasive and does therefore involve less risk. The major problem associated with coiling is a higher aneurysm re-growth rate, and it is speculated that this re-growth is due to underfilling of the aneurysm. In our study, we therefore considered blood flow and resulting wall shear stress in idealized geometries which should represent (underfilled) coiled and clipped aneurysms. We found that underfilling of aneurysms may reduce the shear stress due to a stagnation zone in the aneurysm neck.

Charles Strother, who is Professor in Neuroradiology at the University of Wisconsin, is a highly recognized clinical researcher on cerebral aneurysms. Prof. Strother has established a laboratory specializing in doing canine models of cerebral aneurysms. They have a close collaboration with industry and test new coils before being set in production. Last year we initiated a collaboration with Prof. Strother and his co-workers Jiang Jingfeng and Wieben Oliver at the Department of Medical Physics. Together we aim at validating our blood flow simulations against measurements done with their novel 4D phase-contrast MR technique. Nedless to say, the data obtained from these measurements are far better than obtained by standard techniques used in humans. By doing a thorough validation we hope to be able to demonstrate that computational fluid dynamics (CFD) simulations provide an accurate description of the flow in aneurysms when compared with state-of-the-art measurements. We believe this is the first step towards an understanding of the process that causes the development and rupture of aneurysms.

To summarize, we have established a broad and very fruitful collaboration with clinical researchers on cerebral aneurysms. Our aim so far has been to use quite standard CFD models to investigate hypothesis

about the flow, formulated by medical researchers. The results have helped to obtain new medical insight related to the growth and rupture of aneurysms. It has been a goal to publish new findings in medical journals and to increase the interest in using mathematical models in medicine.

Our models presently neglect the deformations of the vessel walls, because modeling this deformation, which might be important in some cases, introduces several new parameters that are hard to estimate. To make models of clinical relevance, one must find a balance between uncertainty in the modeling and uncertainty due to unknown parameters. The field is only in its early stages of understanding how to choose the right model complexity for a given medical flow problem.

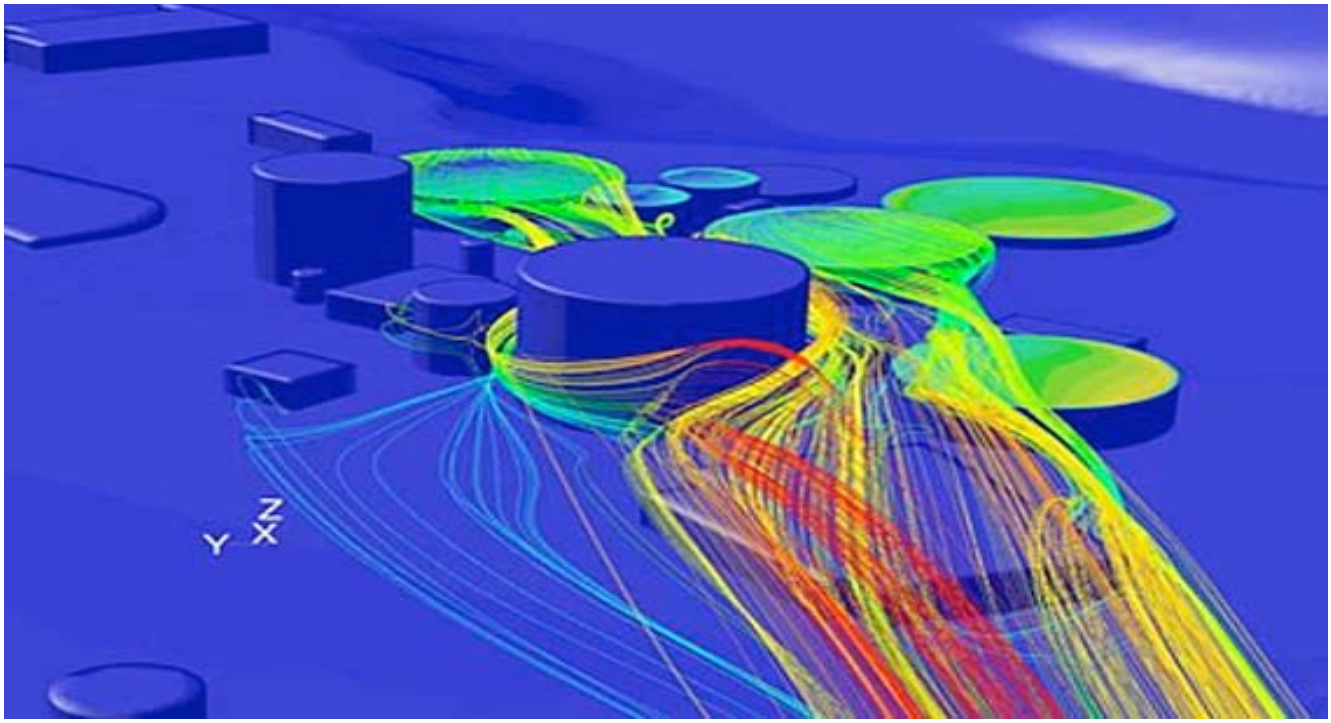
Featured Research 2008: Turbulent Biomedical Flows

In accordance with the promises in the CBC proposal, we have initiated a collaboration with the group on Flow and Turbulence Physics, led by Prof. Bjørn Anders Pettersson Reif, at the Norwegian Defense Research Establishment (FFI). The collaboration has been expanded to include the group led by Prof. Stavros Kassinos at the University of Cyprus (UCy). The main background for this collaboration is the fact that there is limited knowledge in medicine about the importance of turbulent flow in the human body, including the cardiovascular system, but especially the airway system. We want to answer this novel, but computationally challenging, research question. The groups at FFI and UCy are internationally recognized for their strong competence in understanding, modeling, and simulating turbulent flows. Moreover, their physical insight in flow behavior in general is important for the research in the RFS and BFS projects.

The dispersion and transport of aerosols is important in a wide range of biomedical, security, and environmental applications, ranging from medicine delivered in the form of aerosols and the use of inhalator sprays to the dispersion of chemical, biological, radiological, and nuclear (CBRN) agents due to serious accidents, pollution, or terrorist acts. The wide range of applications need a common set of mathematical and numerical tools, and we believe that software and methods from the CM and RFS projects can enhance the efficiency and reliability of implementing new simulation models for aerosol transport and dispersion.

By nature, the prediction of the aerosol transport and dispersion processes is extremely complex. The complexity arises from interdependency of the many complex physical processes involved, such as turbulence, agglomeration/break-ups, gravity, deposition, and physical characteristics and size of the aerosol itself, and its dependence on, for instance, humidity, sun light, and temperature. The project is concerned with numerical simulations at various levels of sophistication and with different objectives. Direct numerical simulations (DNS) will be conducted in order to systematically study fundamental physical characteristics, whereas computationally much cheaper CFD models, such as Large-eddy simulations (LES) and the Reynolds averaged Navier-Stokes (RANS) approaches, are employed in applications.

A major difficulty in biomedical flows is that the turbulence is local in space and time. Transition to/from turbulence in an oscillating average flow field at low Reynolds numbers is particular to biomedi-



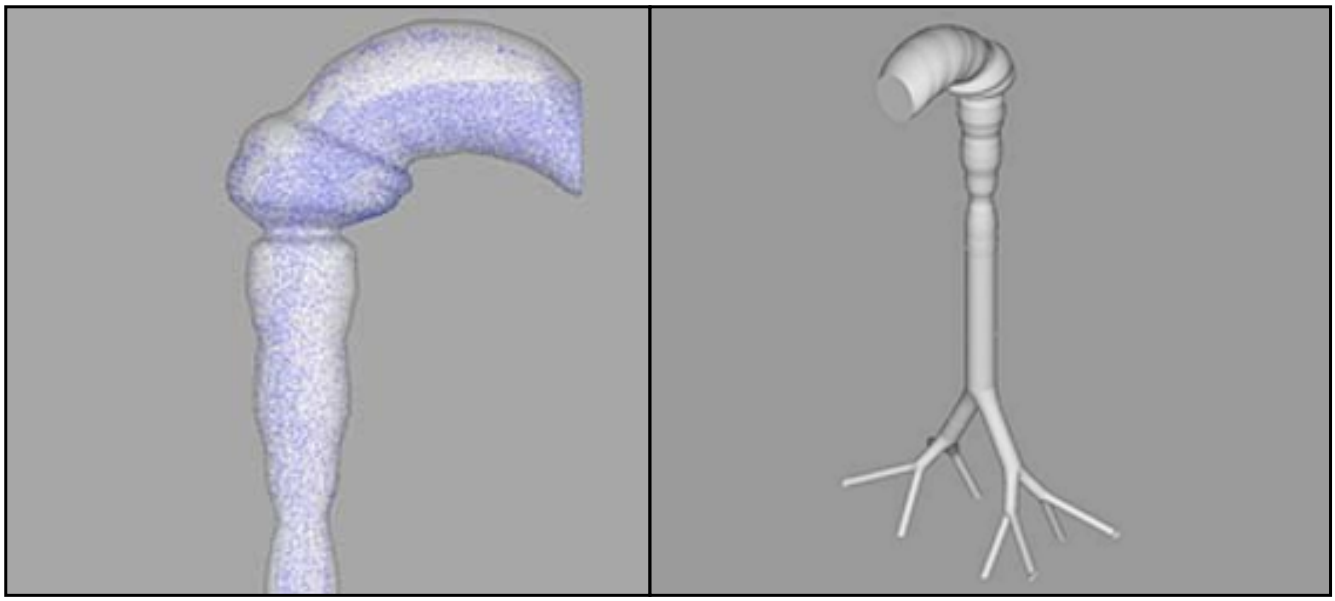
Simulated paths of aerosols generated at aeration ponds at a biological treatment facility. REF: Blatny et al. (2008)

cal flows and therefore not much studied, since most of the research on turbulence has been motivated by industrial applications involving steady-state conditions at high Reynolds numbers. Therefore, addressing local turbulence in biomedical flows calls for fundamental research in fluid mechanics. The collaboration with FFI and UCy is important in this regard, together with physical flow experiments that we aim to perform with Prof. Atle Jensen at the University of Oslo.

In order to facilitate both the fundamental and applied aspects of the research, the activities are divided into two parts: 1) fundamental aspects of aerosol dispersion and transport, and 2) biomedical, safety, and environmental applications. In the first part, DNS and high resolution LES are employed as primary research tools. The objectives are to examine the dispersion processes in different well-defined configurations in order to (i) examine in detail the physical processes involved, (ii) develop sufficient knowledge to improve predictive CFD models, and (iii) to generate benchmark data for CFD model verification and development. The main focus of the study is aerosol dispersion in transitional flows, size distribution and shape effects, and time-varying mean flows. All these subjects are fundamental to biomedical flows in general and flow in the airway system in particular.

In the second class of research activities, state-of-the art CFD modeling strategies, based on both LES and RANS, are applied to a range of applications with focus on biomedical and environmental flows, including health and safety aspects. Existing models are scrutinized using the benchmark data produced in the first part of the project, as well as other benchmark data generated by the CBC partners, in order to identify weaknesses and to suggest remedies to those. Novel concepts including single-point structure-based tensors are investigated, primarily in the development of a new algebraic structure-based turbulence model.

The project was formally started in the beginning 2008, and the main activities during the first year include the following: Development of an Immersed Boundary method for finite volume numerical simulations in complex geometries; theoretical modeling of sprays and double scalar mixing layers; high resolution LES of turbulent boundary layer flows and particle tracking over discreet roughness elements and of particle deposition in the upper part of the human respiratory system; numerical simulations of aerosol transport at a biological treatment facility; development and application of advanced turbulence models that includes turbulence structures; and theoretical investigation of large-scale structures in an axi-symmetric wake using three-component proper orthogonal decomposition. We have in 2008 also laid a foundation for future model development and numerical simulations in the FEniCS-based flow solver framework.



***Left figure**: Close-up of simulated particles in the mouth and glottis regions of the upper airways. REF: Radhakrishnan & Kassinos (2008) ETMM7*
***Right figure**: Computational model of the upper human airways. REF: Radhakrishnan & Kassinos (2008) ETMM7*

International Collaboration

TITLE	NAME	AFFILIATION AFFI	COUNTRY	PROJECT[1]
Prof.	G. Holzapfel	Graz University of Technology	Austria	BFS, NTNU
Dr.	G. Sommer	Graz University of Technology	Austria	BFS, NTNU
Mr.	J. Degroote	Ghent University	Belgium	BFS, NTNU
Prof.	J. Vierendeels	Ghent University	Belgium	BFS, NTNU
Mr.	S. Annerel	Ghent University	Belgium	BFS, NTNU
Prof.	R. J. Spiteri	University of Saskatchewan	Canada	CC
Prof.	W. Chen	Hohai University	China	CM
Prof.	Y. Maday	Laboratoire J.-L. Lions, Université Pierre et Marie Curie and Division of Applied Mathematics,	France	RFS
Prof.	D. Clamond	University of Nice	France	CM
Dr.	M. Burger	University of Münster	Germany	IP
Dr.	B. Erdmann	Zuse Institute Berlin	Germany	CC
Prof.	P. Deuflhard	Zuse Institute Berlin	Germany	CC
Dr.	R. Roitzsch	Zuse Institute Berlin	Germany	CC
Dr.	L. Antiga	Mario Negri Institute for Pharmacological Research, Ranica	Italy	BFS
Prof.	H. Okuda	University of Tokyo	Japan	CM
Dr.	M. Nash	University of Auckland	New Zealand	CB
Prof.	R. Winther	CMA, University of Oslo	Norway	BFS
Mr.	T. K. Karper	CMA, University of Oslo	Norway	BFS
Mr.	K. Holmås	Institute for Energy Technology	Norway	CM
Dr.	S. Glimsdal	Norwegian Geotechnical Institute	Norway	CM
Prof.	E. Rønqvist	NTNU	Norway	RFS
Prof.	A. Malthe-Sørensen	PGP, University of Oslo	Norway	CM
Mr.	H. Holmås	Scandpower Technology	Norway	CM
Prof.	R. Haaverstad	St. Olav Hospital, Trondheim	Norway	BFS, NTNU
Mr.	J. Skogseid	StatoilHydro	Norway	CG
Mr.	O. Lauvrak	StatoilHydro	Norway	CG
Mr.	T. Løseth	StatoilHydro	Norway	CG
Dr.	T. Sømme	University of Bergen	Norway	CG
Dr.	J. Isaksen	University of Tromsø and University Hospital of Northern Norway	Norway	BFS
Prof.	T. Ingebrigtsen	University of Tromsø and University Hospital of Northern Norway	Norway	BFS
Dr.	R. Hren	University of Lubljana	Slovenia	CB
Prof.	G. Holzapfel	Royal Institute of Technology	Sweden	BFS, NTNU
Dr.	S. Deparis	EPFL Lausanne	Switzerland	RFS
Dr.	A. V. Panfilov	Utrecht University	The Netherlands	CB
Prof.	P. Hogeweg	Utrecht University	The Netherlands	CB
Dr.	R. Kelderman	Utrecht University	The Netherlands	CB
Prof.	P. Taggart	University College Hospital London	United Kingdom	CB
Dr.	G. N. Wells	University of Cambridge	United Kingdom	CM, RFS
Dr.	C. P. Bradley	University of Oxford	United Kingdom	CB
Dr.	R. H. Clayton	University of Sheffield	United Kingdom	CB
Dr.	M. Sosonkina	Ames Lab	USA	CM
Dr.	M. G. Knepley	Argonne National Lab	USA	CM
Prof.	Y. Maday	Brown University, Providence	USA	RFS
Dr.	J. Werne	Colorado Research Associates	USA	RFS
Prof.	R. C. Kirby	Texas Tech	USA	CM
Dr.	C. Ni	The University of Arizona	USA	CM
Prof.	J. T.-C. Yeh	The University of Arizona	USA	CM
Dr.	J. Zhu	The University of Arizona	USA	CM
Mr.	A. R. Terrel	University of Chicago	USA	CM
Prof.	E. M. Arruda	University of Michigan, Ann Arbor	USA	RFS
Dr.	K. Garikipati	University of Michigan, Ann Arbor	USA	RFS
Prof.	K. Grosh	University of Michigan, Ann Arbor	USA	RFS
Prof.	U. Ruede	University of Erlangen	Germany	CG

[1] *The abbreviations are explained in the Appendix*

Education and Outreach

The Simula School of Research and Innovation AS (SSRI)

As described in last year's report, CBC has entered a close partnership with the Simula School of Research and innovation (SSRI). The partnership with SSRI helps to streamline our educational activities, and aims to provide high quality working conditions for research trainees, PhD students and postdoctoral fellows. In 2008 a total of 3 research trainees, 5 PhD candidates and 2 postdoctoral fellows at CBC have been affiliated with SSRI.

Throughout 2008, SSRI has focused on two specific initiatives designed to enhance the competence of the students and postdoctoral fellows in research dissemination and in innovation and commercialisation. The course Communicating Research in Science was developed in cooperation with Penn State University, and has been offered for the first time in the spring term and turned out to be a huge success. The Innovation and Entrepreneurship course was developed in cooperation with Simula Innovation, and the first student intake has been planned for January 2009.

By affiliating the PhD students and postdoctoral fellows working on CBC projects with SSRI, the candidates are ensured to get as optimal conditions for their research as possible. This is particularly useful for personnel recruited abroad, for which SSRI serves as a one-step link toward the university system. In addition, this connection provides an opportunity for extended research activity since SSRI finances positions as research trainee, PhD and postdoctoral fellow for projects that share a common scientific base with activities in CBC.

Python for Scientific Computations

There is an increasing awareness world wide that Python-based technologies are promising for scientific computing software. Several people at CBC have high competence on and long experience with these technologies. We have developed books, university courses, short courses, and one-day tutorials with the purpose of teaching Python and how it can be useful in computational science.

In 2008, we contributed with Python technology to the intensive graduate course "Programming in Science and Technology" held jointly two days at Lund University and an additional two days at Uppsala University in Sweeden:
http://www.lunarc.lu.se/Courses/programming-in-science-and-technology
The course series is part of the Swedish National Graduate School for PhD students in Scientific Computing, and had more than 20 participants. Our contributions there were highly acclaimed in the student critique. We also gave a similar course at the Norwegian University of Life Science at Ås and at the University of Erlangen in Germany.

Our Springer book "Python Scripting for Computational Science" continues to sell very well and saw its second printing of the third edition in 2008. The book and our courses certainly attracts attention to CBC and our comprehensive Python competence. We see that several researchers visit CBC with the purpose of getting help with utilizing Python for high-performance computing.

The annual report of 2007 described in detail our new introductory course, at the University of Oslo, on Python programming for computational science applications (INF1100). We continued the work on improving and further developing this course and the associated book in 2008. The course received excellent student critique and now constitutes our main effort to increase the general recruitment to the scientific fields covered by CBC. The book is expected to be finished and published internationally in 2009.

Lecture Series

CBC researchers are active in teaching regular courses at all levels at the University of Oslo, usually as part of adjunct positions at the Department of Informatics. A total of 10 researchers taught 12 courses in 2008. In addition, Dr. Achim Schroll gave a course at Lund University, and Prof. Xing Cai gave lectures at the Winter School on Parallel Computing (Geilo, Norway).

A special CBC lecture series was given at Simula in the period August 4-8, 2008: Foundations of Finite Element Computing, lectured by Prof. Rob Kirby (Texas Tech), Dr. Matt Knepley (Argonne) and Dr. Dmitry Karpeev (Argonne). Several advanced finite element topics were covered, such as transformations and the Sieve concept, as well as their implementational counterparts. The lecture series featured 23 participants, 5 outside CBC, from 6 different countries.

In the first quarter of 2008, the Computational Middleware project arranged a programming laboratory twice a week, lasting three hours, where CBC staff and guests could get hands-on supervision in using various software tools (FEniCS, Python, C++, PETSc, Trilinos, to mention some) that are widely applied in CBC projects.

Appendix

In the appendices below, we use several abbreviations:

ADM = The Administration unit at Simula
BFS = Biomedical Fluids and Structures (CBC project)
CB = Computational Biology (CBC project)
CC = Cardiac Computations (CBC project)
CM = Computational Middleware (CBC project)
CG = Computational Geoscience (CBC project)
F = Female
FFI = Norwegian Defence Research Establishment
HOST = Simula Research Laboratory (SRL)
IP = Inverse Problems (CBC project)
M = Male
NTNU = Norwegian University of Science and Technology
RCN = Research Council of Norway
RFS = Robust Flow Solvers (CBC project)
SSRI = Simula School of Research and Innovation
UCy = University of Cyprus
UiO = University of Oslo
UmU = Umeå University

Staff

SENIOR SCIENTISTS 2008: 28 PEOPLE 13,4 MAN-YEARS

Name	Gender	Period	CBC share	Project	Funding
Achim Schroll	M	01.01.2008 - 31.12.2008	100 %	CG	SSRI
Anders Logg	M	01.04.2007-31.07.2009	100 %	RFS	HOST
Andrew D. McCulloch	M	01.04.2007-30.09.2009	10 %	BFS/CC	RCN grant 162730
Are Magnus Bruaset	M	01.01.2008-31.03.2017	50 %	CG	SSRI
Aslak Tveito	M	01.08.2007-31.03.2017	25 %	CC	HOST
Bjørn Anders P. Reif	M	01.01.2008 - 31.12.2008	30 %	CBC @ FFI/UCy	CBC
Bjørn Fredrik Nielsen	M	01.08.2007-31.03.2017	100 %	IP	HOST
Bjørn Skallerud	M	24.05.2007-31.03.2017	20 %	BFS	NTNU
Carl Erik Wasberg	M	01.01.2008 - 31.12.2008	30 %	CBC @ FFI/UCy	FFI/UCy
Geir K. Pedersen	M	01.01.2008-31.06.2009	10 %	BFS	CBC
Glenn Terje Lines	M	01.08.2007-31.03.2017	100 %	CC	HOST
Hans Petter Langtangen	M	01.04.2007-31.03.2017	100 %	CM	HOST
Harald Osnes	M	01.08.2007-31.12.2008	40 %	CC	50% CBC + 50% UiO
Joakim Sundnes	M	01.04.2007-31.03.2017	50 %	CC	HOST
Kenneth Hvistendahl Karlsen	M	01.01.2008-31.12.2008	10 %	BFS/CC	CBC
Kent-Andre Mardal	M	01.04.2007-31.03.2017	100 %	BFS	RCN grant 170650
Kirsten ten Tusscher	F	10.06.2008-31.05.2011	100 %	CB	HOST
Leif Rune Hellevik	M	24.05.2007-31.03.2017	45 %	BFS	NTNU
Mats G. Larson	M	01.04.2007-31.05.2009	40 %	RFS	50% CBC + 50% UmU
Ola Skavhaug	M	01.04.2007-01.04.2009	85 %	CM	CBC
Per Grøttum	M	01.08.2007-31.12.2008	20 %	IP	HOST
Scott Baden	M	11.06.2007-10.06.2009	20 %	CM	CBC
Stavros Kassinos	M	01.01.2008- 31.12.2008	10 %	CBC @ FFI/UCy	FFI/UCy
Svein Linge	M	01.04.2007-01.07.2008	60 %	BFS	CBC
Thor Gjesdal	M	01.01.2008- 31.12.2008	30 %	CBC @ FFI/UCy	FFI/UCy
Victor Haughton	M	15.06.2008-14.06.2010	6 %	BFS	CBC
Xing Cai	M	01.04.2007-31.03.2017	100 %	CC/CM	HOST
Øyvind Andreassen	M	01.01.2008- 31.12.2008	10 %	CBC @ FFI/UCy	FFI/UCY

POST DOCS 2008: 17 PEOPLE 8,8 MAN-YEARS

Name	Gender	Period	CBC share	Project	Funding
Alf Emil Løvgren	M	01.04.2007-31.12.2009	100 %	RFS	CBC
Dimokratis Gregoriadis	M	01.01.2008- 31.12.2008	50 %	CBC @ FFI/UCy	92 %FFI/UCy + 8% CBC
Harikrishnan Radkakrishnan	M	01.01.2008- 31.12.2008	50 %	CBC @ FFI/UCy	93 %FFI/UCy + 8% CBC
Harish Narayanan	M	24.06.2008-23.06.2010	100 %	RFS	RCN grant 180450/V30
Malin Ljungberg	F	01.05.2007-01.02.2008	100 %	CM	CBC
Mary MacLachlan	F	01.04.2007-30.09.2008	100 %	CC	RCN grant162730
Mikael Mortensen	M	01.01.2008- 31.12.2008	40 %	CBC @ FFI/UCy	FFI/UCy
Monica Hanslien	F	01.08.2007-01.01.2009	100 %	CC	RCN grant 171164
Murat Tutkun	M	03.10.2008 - 31.12.2008	100 %	CBC @ FFI/UCy	CBC
Ola Marius Lysaker	M	01.10.2008-31.08.2010	100 %	IP	HOST
Pan Li	M	15.08.2008-15.05.2010	100 %	CC	HOST
Pearu Peterson	M	07.05.2007-30.04.2008	100 %	CM	CBC
Robert Artebrant	M	01.10.2007-30.09.2009	100 %	CC	SSRI
Samuel Wall	M	26.05.2008-31.12.2010	100 %	CC	RCN grant162730
Stuart Clark	M	01.01.2008-31.03.2011	100 %	CG	SSRI
Thomas Vik	M	01.01.2008- 31.12.2008	20 %	CBC @ FFI/UCy	FFI/UCy
Victorien Prot	M	01.09.2008-31.12.2009	100 %	BFS	CBC

PHD STUDENTS 2008: 16 PEOPLE 11,3 MAN-YEARS

Name	Gender	Period	CBC share	Project	Funding
Didem Unat	F	11.09.2007-10.09.2011	100 %	CM	CBC
Joachim Berdal Haga	M	01.01.2008-13.08.2009	100 %	CG	SSRI
Johan Elon Hake	M	01.08.2007-15.04.2009	100 %	CC	HOST
Kristian Valen-Sendstad	M	21.05.2008-20.05.2011	100 %	BFS/RFS	SSRI
Kristoffer Selim	M	01.01.2008-31.12.2010	100 %	RFS	RCN grant 180450/V30
Martin Alnæs	M	01.08.2007-31.07.2009	100 %	CC	RCN grant162730
Murat Tutkun	M	01.01.2008- 03.10.2008	27 %	CBC @ FFI/UCy	FFI/UCy
Oddrun Myklebust	F	15.08.2008-26.01.2009	100 %	BFS	SSRI
Omal al-Khayat	M	01.01.2008-31.03.2009	100 %	CG	SSRI
Paul Roger Leinan	M	10.09.2007-10.09.2011	100 %	BFS	NTNU
Rolv Erlend Bredesen	M	01.04.2007-27.01.2011	100 %	CM	90 % UIO + 10 % CBC
Sigrid Kaarstad Dahl	F	15.08.2008-14.08.2011	100 %	BFS	CBC
Tim Dorscheidt	M	01.11.2008-01.11.2011	100 %	CB	CBC
Tomas Syrstad Ruud	M	01.08.2007-30.11.2008	100 %	IP	HOST
Victorien Prot	M	24.05.2007-31.08.2008	100 %	BFS	CBC
Wenjie Wei	M	01.10.2008-01.10.2011	100 %	CM	SSRI

Technical and administrative staff 2008: 12 PEOPLE 5,8 MAN-YEARS

Name	Gender	Position	Period	CBC share	Project	Funding
Anders Helgeland	M	Research Scientist	01.06.2007-31.12.2009	20 %	BFS	CBC
Emma Wingstedt	F	Research Scientist	01.01.2008- 31.12.2008	30 %	CBC @ FFI/UCy	FFI/UCy
Hege Johnsrud	F	Financial Officer	01.04.2007-31.03.2018	5 %	ADM	HOST
Ilmar Wilbers	M	Scientific Programmer	01.01.2008-31.12.2008	50 %	CM	25% UiO+75% CBC
Johannes Hofaker Ring	M	Scientific Programmer	01.01.2008-31.12.2008	80 %	CM	CBC
Kristian Valen Senstad	M	Research Trainee	21.05.2007-20.05.2008	100 %	BFS	SSRI
Oddrun Myklebust	F	Research Trainee	15.08.2007-14.08.2008	100 %	BFS	SSRI
Peter Brune	M	Scientific Programmer	14.06.2008-07.09.2008	100 %	CM	CBC
Sigrid Kaarstad Dahl	F	Research Trainee	15.08.2007-14.08.2008	100 %	BFS	CBC
Tom David Atkinson	M	Administrative Manager	01.05.2007-31.03.2017	100 %	ADM	CBC
Wenche Angel	F	Executive Officer Economy	01.04.2007-31.03.2017	10 %	ADM	HOST
Wenjie Wei	M	Research Trainee	01.10.2007-30.09.2008	100 %	CM	SSRI

GUEST RESEARCHERS 2008: 2 PEOPLE 0,7 MAN-YEARS

Name	Gender	Period	Place	CBC share	Project	Funding
Joseph Werne	M	20.10.2008 - 21.11.2008	FFI	100 %	CBC @ FFI/UCy	FFI/UCy
Ralph Lorentzen	M	01.01.2008-31.12.2008	CBC	60 %	CG	HOST

Accounting and Budget

Below, we present the main figures regarding the CBC budget and funding. The operating revenues and expenses represent the funding and cost that we control ourselves. The income in kind and operating expenses in kind presents representative figures from activities (people) within the CBC project, but with the funding and costs outside of CBC's books.

By further expanding the scope of CBC and establishing collaboration with The Norwegian Defence Research Establishment, the University of Cyprus and the Computational Geoscience project financed by StatoilHydro through Simula School of Research and Innovation the SFF grant from the Research Council of Norway now represents less than 1/4 of the total funding of CBC, instead of the approximately 2/3 that was originally intended in our proposal.

OPERATING REVENUES	Note	Account 2007	Budget 2008	Account 2008	Budget 2009
RCN CoE founding		5 664	7 500	7 500	8 160
Allocation from earlier years		0	1 478	1 478	-117
Host - Simula Research Laboratory		6 541	9 577	9 639	9 651
Other income RCN	1	1 556	3 993	4 131	3 915
Other income	2	48		16	
Sum operating revenues		**13 809**	**22 548**	**22 764**	**21 609**
Income in kind:					
Simula School of Research and Innovation	3	1 103	2 676	5 842	5 760
Norwegian University of Science and Technology	4	1 425	1 168	1 131	1 320
University of Oslo	5	641		792	960
University of Umeå	6	108		152	160
Host - Simula Research Laboratory	7			636	1 000
Norwegian Defence Research Establishment/University of Cyprus	8			2 032	
Sum income in kind		**3 277**	**3 844**	**10 585**	**9 200**
Total income		**17 086**	**26 392**	**33 349**	**30 809**

OPERATING EXPENSES	Note	Account 2007	Budget 2008	Account 2008	Budget 2009
Cost of labour		8 388	16 786	16 330	16 000
Indirect costs	9	1 996	3 013	3 255	4 060
Outsourcing of R&D services	10	83	891	866	
Other operating expenses	11	1 864	2 153	2 430	3 300
Sum operating expenses		**12 331**	**22 843**	**22 881**	**23 360**
Operating expenses in kind:					
Cost of labour		2 474	2 691	7 622	6 440
Indirect costs	9	359	673	1 905	1 840
Other operating expenses	11	444	480	1 058	920
Sum operating expenses in kind		**3 277**	**3 844**	**10 585**	**9 200**
Total operating expenses		**15 608**	**26 687**	**33 466**	**32 560**
Year end allocation		**1 478**	**-295**	**-117**	**- 1 751**

Note 1: *Other income RCN:*
162730: YFF - Computing the mechanics of the heart = 1 400
171164: Numerical simulations of cardiac arrhythmia and defibrillation = 744
170650: Mixed Methods for the Stress-Displacement Formulation of Elasticity - A Software Framework for Advanced Finite Elements Methods = 744
180450: YFF - Automation of Error Control with Application to Fluid-Structure Interaction in Biomedicine = 1 243
Note 2: *Other income: Royalties = 4; Sold equipment = 12*
Note 3: *Simula Research Laboratory's subsidiary Simula School of Research and Innovation (SSRI) is responsible for all educational activities in Simula Resarch Laboratory. The Simula School has financed the work of two post docs R. Artebrant and S. Clark, and three research trainees becoming Ph.D. students during the year K.V. Sendstad, O. Myklebust and W. Wei. StatoilHydro is financing 1.5 researchers: H.J. Schroll and prof. A.M. Bruaset, and two Ph.D. students: O. Al-Khayat and J.B. Haga, through SSRI*
Note 4: *Contributions from the Norwegian University of Science and Technology (NTNU)*
Note 5: *Contributions from the University of Oslo: One Ph.D. student R. E. Bredesen and part time funding of researcher H. Osnes*
Note 6: *Contributions from the University of Umeå: Part time funding of prof. M. Larson*
Note 7: *Contributions from the host - Simula Research Laboratory: Post doc P. Li, and funding of contribution from managing director prof. A. Tveito and funding of administration services*
Note 8: *Contribution from the Norwegian Defence Research Establishment (FFI) / University of Cyprus (UCy)*
Note 9: *Indirect costs cover the cost of offices and infrastructure to all employees*
Note 10: *Outsourced development work done by Sintef*
Note 11: *Other operating expenses include the cost of scientific equipment, travelling, workshops, seminars and guests*

Publications

CBC only reports publications where a significant part of the research has been funded by CBC. By this we mean that at least one of the authors of the reported publications must have his/her main affiliation with CBC, and has contributed to the publication as laid out in Simula's publication guidelines: http://simula.no/research/publication-guidelines/

Publications from people with part time positions at CBC are generally not counted, unless the research is specifically performed as part of the CBC project. Such exceptions from the main rule are few, and must in all cases be approved by the director of the center.

Articles in International Journals

23) E. Berg, **B. H. Skallerud**, and C. Thaulow. Two-parameter fracture mechanics and circumferential crack growth in surface cracked pipelines using Line-Spring elements. *Engineering Fracture Mechanics* **75**, no.1, 17-30, 2008.

24) E. Berg, E. Østby, C. Thaulow, and **B. H. Skallerud**. Ultimate fracture capacity of pressurised pipes with defects - comparisons of large scale testing and numerical simulations. *Engineering Fracture Mechanics* **75**, 2352-2366, 2008.

25) J. M. Blatny, **B. A. Pettersson Reif**, G. Skogan, **Ø. Andreassen**, E. A. Høiby, E. Ask, V. Waagen, D. Aanonsen, I. S. Aaberge, and D. A. Caugant. Tracking airborne Legionella and Legionella pneumophila at a biological treatment plant. *Environmental Science and Technology*, **42**, 7360-7367, 2008.

26) S. G. Campbell, S. N. Flaim, C. H. Leem, **A. D. McCulloch.** Mechanisms of transmurally-varying myocyte electromechanics in an integrated computational model. *Phil Trans Royal Soc A*, **366**, no. 1879, 3361-3380, 2008.

27) G. M. Coclite, **K. H. Karlsen**, and N. H. Risebro. An explicit finite difference scheme for the Camassa-Holm equation. *Adv. Differential Equations*, **13**, no. 7–8, 681–732, 2008.

28) **S. R. Clark** and R. D. Müller. Convection models in the Kamchatka region using imposed plate motion and thermal histories. *Journal of Geodynamics*, **46**, no. 1-2, 1-9, 2008.

29) **S. R. Clark**, D. Stegman, and R. D. Müller. Episodicity in back-arc tectonic regimes. *Physics of the Earth and Planetary Interiors*, **171** (Special Issue on Recent Advanced in Computational Geodynamics: Theory, Numerics and Applications), 265-279, 2008.

30) J. D. Feala, J. H. Omens, G. Paternostro, **A. D. McCulloch**. Discovering regulators of the drosophila cardiac hypoxia response using automated phenotyping technolog. *Annals of the New York Academy of Science* 1123, 169-177, 2008.

31) **D. G. Grigoriadis**, **S.C. Kassinos** and E. Votyagov. Immersed boundary method for the MHD flows of liquid metals. *Journal of Computational Physics*, **228**, no. 3, 903-920, 2008.

32) **J. E. Hake** and **G. T. Lines**. Stochastic binding of Ca2+ in the dyadic cleft: continuous vs. random-walk description of diffusion. *Biophysical Journal*, **94** no. 11, 4184-4201, 2008.

33) H. Holmås, D. Clamond, and **H. P. Langtangen.** A pseudospectral Fourier method for a 1D incompressible two-fluid model. *International Journal for Numerical Methods in Fluids*, **58**, 639-658, 2008.

34) J. Jansson and **A. Logg**. Algorithms and data structures for multi-adaptive time-stepping. *ACM Trans. Math. Software*, **35**, no. 3, 1-24, 2008.

35) T. Karper, **K.-A. Mardal**, and R. Winther. Unified finite element discretizations of coupled Darcy-Stokes flow. *Numerical Methods for Partial Differential Equations*, **25**, no. 2, 311-326, 2008.

36) R. H. Keldermann, **K. t. Tusscher**, M. Nash, R. Hren, P. Taggart, and A. V. Panfilov. Effect of heterogeneous APD restitution on VF organization in a model of the human Ventricles. *Am. J. Physiol. Heart Circ Physiology*, **294**, no. 2, H764-H774, 2008.

37) R. C. P. Kerckhoffs, J. Lumens, K. Vernooy, J. H. Omens, L. J. Mulligan, T. Delhaas, T. Arts, **A. D. McCulloch**, F. W. Prinzen. Cardiac resynchronization: Insight from experimental and computational models. *Progress in Biophysics and Molecular Biology*, **97**, no. 2-3, 543-61, PMID: 18417196, 2008.

38) R. C. Kirby, and **A. Logg**. Benchmarking domain-specific compiler Optimizations for variational forms. *ACM Transactions on Mathematical Software*, **35**, no. 2, 1-18, 2008.

39) **M. Larson** and A. Målqvist. A posteriori error estimates for mixed finite element approximations of elliptic problems. *Numerische. Mathematik*, **108**, 487-500, 2008.

40) W. Li, V. Gurev, **A. D. McCulloch**, N. A. Trayanova. The role of mechanoelectric feedback in vulnerability to electric shock. *Progress in Biophysics and Molecular Biology*, **97**, no. 2-3, 461-78, 2008.

41) **S. O. Linge, G. T. Lines, J. Sundnes,** and **A. Tveito**. On the frequency of automaticity during ischemia in simulations based on stochastic perturbations of the Luo-Rudy 1 model. *Computers in biology and medicine*, **38**, no. 11-12, 1218-1227, 2008.

42) K. B. Lunde, O. A. Foss, L. Fosse, and **B. H. Skallerud**. Constitutive models for constrained compression of unimpacted and impacted human morselized bone grafts. *Journal of Biomechanical Engineering*, **130**, no. 6, 2008.

43) K. B. Lunde, O. A. Foss, and **B. H. Skallerud**. On the applicability of bovine morsellized Cortico-Cancellous bone as a substitute for human morsellized Cortico-Cancellous bone for in-vitro mechanical testing. *Journal of Biomechanics*, **41**, no. 16, 3469-3474, 2008.

44) K. B. Lunde, M. Sletmoen, B. T. Stokke, and **B. H. Skallerud**. The fluid phase of morsellized bone: Characterization of viscosity and chemical composition. *Journal of The Mechanical Behavior of Biomedical Materials*, **1**, no. 2, 199-205, 2008.

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48) K. B. Oelgaard and **A. Logg**, G. N. Wells. Automated code generation for discontinuous Galerkin methods. *SIAM J. Sci. Comput.*, **31**, no. 2, 849-864, 2008.

49) H. Sira, T. Nordsveen, **H. P. Langtangen**, R. Shulkes. Analysis of a 1D ilncompressible two-fluid model including artificial diffusion. *IMA Journal of Applied Mathematics*, **4**, no. 73, 651-667, 2008.

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51) **K. t. Tusscher**, A. V. Panfilov. Modeling of the ventricular conduction system. *Prog Bioph Mol Biol*, **96**, no. 1-3, 152-170, 2008.

52) **M. Tutkun**, P. B. V. Johansson and W. K. George. Three-component vectorial proper orthogonal decomposition of axisymmetric wake behind a disk. *AIAA Journal.*, **46**, 1118-1134, 2008.

53) **A. Tveito**, **G. T. Lines**. A condition for setting off ectopic waves in computational models of excitable cells. *Mathematical Biosciences*, **213**, no. 2, 141-150, 2008.

54) J. T.-C. Yeh, Cheng-H. Lee, Kuo-C. Hsu, W. A. Illman, W. Barrash, **X. Cai**, J. Daniels, E. Sudicky, L. Wan, G. Li, C. L. Winter. A view toward the future of subsurface characterization: CAT scanning groundwater basins. *Water Resources Research*, **44**, no. 0, W03301, 2008.

55) S. Ås, **B. H. Skallerud**, and B. W. Tveiten. Surface roughness characterization for fatigue life predictions using finite element analysis. *International Journal of Fatigue*, **30**, no. 12, 2200-2209, 2008.

Refereed Proceedings

9) **S. K. Dahl, L. R. Hellevik,** and **B. Skallerud**. A 2D patient-specific FSI assessment of mitral valve dynamics during diastolic filling. In: *8th.World Congress on Computational Mechanics (WCCM8)/5th European Congress on Computational Methods in Applied Sciences and Engineeering (ECCOMAS 2008)*, Venice, Italy, 2008.

10) **D. G. E. Grigoriadis** and **S. C. Kassinos**. Efficient simulations of wall bounded magnetohydrodynamic flows. In: *6th GRACM, International Congress on Computational Mechanics*, Thessaloniki, paper No. 2101 (ISBN 978-960-6706-08-0), 2008.

11) **D. G. E. Grigoriadis** and **S. C. Kassinos**. Lagrangian particle dispersion in turbulent flow over a wall mounted obstacle. In: *7th International ERCOFTAC Symposium on Engineering Turbulence Modeling and Measurements – ETMM7*, **2**, 486 – 491, 2008.

12) **H. P. Langtangen** and **X. Cai**. On the efficiency of Python for high-performance computing: A case study involving stencil updates for partial differential equations. In: *Modeling, Simulation and Optimization of Complex Processes*, ed. by H. G. Bock, E. Kostina, H. X. Phu, and R. Rannacher, 337-358, Springer, 2008.

13) **M. Mortensen, B. A. Pettersson Reif** and C. A. Langer. Modelling adverse pressure-gradient boundary layers using the nonlinear v2f model in combination with a structure based model. In: *7th International ERCOFTAC Symposium on Engineering Turbulence Modeling and Measurements – ETMM7*, **1**, 101 – 106, 2008.

14) E. Olsø, E. Berg, K. H. Holthe, B. Nyhus, **B. H. Skallerud**, C. Thaulow, and E. Østby. Effect of embedded defects in pipelines subjected to plastic strains during operation. *ISOPE*, 2008.

15) **H. Radhakrishnan** and **S. C. Kassinos.** Modeling particle deposition in the human lungs. In: *6th GRACM, International Congress on Computational Mechanics*, Thessaloniki, paper no. 2104 (ISBN 978-960-6706-08-0), 2008.

16) **H. Radhakrishnan** and **S. C. Kassinos.** Using LES to model turbulent particle transport in lungs. In: *7th International ERCOFTAC Symposium on Engineering Turbulence Modeling and Measurements – ETMM7*, **3**, 856 – 861, 2008.

17) **M. Siklosi**, O. Jensen, R. Tew, and **A. Logg**. Multiscale modeling of the acoustic properties of lung parenchyma. In: *Modelling of the Respiratory System Biomechanical, Computational and Mathematical Aspects*, **23**, 78-97, 2008.

18) **M. Tutkun**, W. K. George, J. Delville , J. M. Foucaut, S. Coudert and M. Stanislas. Space-time correlations from a 143 hot-wire rake in a high Reynolds number turbulent boundary layer. *AIAA-Paper: 2008-4239*, 5th AIAA Theoretical Fluid Mechanics Conference, Seattle, Washington, USA, 2008.

Books

1) **H. P. Langtangen**. *Python scripting for computational science*, Third Edition, Springer-Verlag, ISBN: 978-3-540-73915-9, 2008.

2) **X. Cai** and T.-C. J. Yeh (editors). *Quantitative information fusion for hydrological sciences*, Springer-Verlag, ISBN: 978-3-540-75383-4, 2008

Chapters in Books

3) N. Bouhmala and **X. Cai**. A multilevel greedy algorithm for the Satisfiability problem. In: *Advances in Greedy Algorithms*, ed. by Witold Bednorz. IN-TECH Education and Publishing, Vienna, chap. 3, 39-54, 2008.

4) **H. P. Langtangen** and **X. Cai**. On the efficiency of Python for high-performance computing: A case study involving stencil updates for partial differential equations. In: *Modeling, Simulation and Optimization of Complex Processes*, ed. by H. G. Bock, E. Kostina, H. X. Phu, and R. Rannacher, 337-358, Springer, 2008.

5) **A. Logg**. Att lösa en differentialekvation. In: *Matematikens Rikedomar*, ed. by O. Helenius and K. Wallby. Nationellt centrum för matematikutbildning, NCM, 2008.

PhD Theses

1) **V. E. Prot**. Modelling and numerical analysis of the porcine and human mitral apparatus. *PhD thesis in Biomechanics*, Norwegian University of Science and Technology, Faculty of Engineering Science and Technology, Department of Structural Engineering, 2008.

2) **M. Tutkun**. Structure of zero pressure gradient high Reynolds number turbulent boundary layers. *PhD thesis in Thermo and Fluid Dynamics*, Department of Applied Mechanics, Chalmers University of Technology, Sweden, 2008.

Proceedings without Referee

1) **H. P. Langtangen** and **A. Logg**. Trends in computational mechanics software. In: *21st Nordic Seminar on Computational Mechanics*, 21st Nordic Seminar on Computational Mechanics, ed. by T. Kvamsdal, K. M. Mathisen, B. Pettersen, 2008.

2) **A. Logg**. An overview of the FEniCS project. In: *21st Nordic Seminar on Computational Mechanics*, ed. by T. Kvamsdal, K. M. Mathisen, B. Pettersen, 2008.

3) **A. E. Løvgren**, **S. Linge**, **K.-A. Mardal**, **V. Haughton**, and **H. P. Langtangen**. CFD analysis of cerebrospinal fluid flow in the cranio-cervical region. In: *21st Nordic Seminar on Computational Mechanics*, ed. by T. Kvamsdal, K. M. Mathisen, B. Pettersen, 2008.

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5) **H. Narayanan**, K. Garikipati, and **A. Logg**. Collaborative computational frameworks and the growth problem. In: *The Mathematics of Growth and Remodelling of Soft Biological Tissues*, ed. by D. Ambrosi, K. Garikipati and E. Kuhl, vol. 39/2008, pp. 29-31, Mathematisches Forschungsinstitut Oberwolfach, European Mathematical Society Publishing House. Oberwolfach Reports, 2008.

6) K. B. Oelgaard, G. N. Wells, and **A. Logg**. Automated computational modelling for solid mechanics. In: *IUTAM Symposium on Theoretical, Modelling and Computational Aspects of Inelastic Media*, 2008.

7) **B. Skallerud**, A Winnem, LL Randeberg, and L Svaasand. On the biomechanical analysis of bruises. In: *21st Nordic Seminar on Computational Mechanics*, ed. by T. Kvamsdal, K. M. Mathisen, B. Pettersen, 2008.

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Talks

52) **O. Al-Khayat**, **A. M. Bruaset** and **H. P. Langtangen**. Numerical modeling of turbidity flow with the Lattice Boltzmann Method. Talk at the CBC workshop: *Computational Geoscience Workshop.*, 2008

53) **O. Al-Khayat**, **H. P. Langtangen**, and **A. M. Bruaset**. A coupled Lattice Boltzmann model for a turbulent sand-laden fluid flow. Talk at the *DSFD conference*, Brazil, 2008.

54) **O. Al-Khayat**, T. Løseth, **A. M. Bruaset**, and **H. P. Langtangen**. Particle-based methods in the modeling of turbidity currents and turbidities, Talk at the *33rd International Geological Congress*, Oslo, 2008.

55) **M. S. Alnæs**, and **K.-A. Mardal**. SFC - the SyFi form compiler, Talk at the *FEniCS 08 Workshop*, Baton Rouge, Louisiana, 2008.

56) **X. Cai**. Simulation of tsunami propagation. Talk at the *2nd eScience Meeting*, Geilo, Norway, 2008.

57) **X. Cai**. High-performance computing on distributed-memory architecture. Lecture at the *2008 Winter School on Parallel Computing*, Geilo, Norway, 2008.

58) **X. Cai**. Parallel computing; why & how?. Lecture at the *2008 Winter School on Parallel Computing*, Geilo, Norway, 2008.

59) **X. Cai**. Use of advanced computing in tomographic surveys. Talk at *PARA'08*, Trondheim, Norway, 2008.

60) **X. Cai**. Resource-efficient simulation of tsunami wave propagation on parallel computers. Invited talk at *2nd International Symposium for Integrated Predictive Simulation System for Earthquake and Tsunami Disaster*, Tokyo, Japan, 2008.

61) **S. R. Clark**. Lithospheric modelling: Research directions at Simula. Talk at the *GeoMath08 Workshop*, Santa Fe, New Mexico, 2008.

62) **S. R. Clark**. Handling uncertainty in numerical models of sedimentary deposition: A stochastic approach. Talk at the *33rd International Geological Congress*, Oslo, 2008.

63) **S. R. Clark**. Slabs in the mantle - Dynamic topography and mantle rheology in the South-Western Pacific. Talk at the *33rd International Geological Congress*, Oslo, 2008.

64) **S. R. Clark**. Time-dependant evolution of subduction zones. Invited Talk at *Ludwig-Maximilians University (LMU)*, Munich, Germany, 2008.

65) **S. R. Clark**. Geodynamics: The Physics and mathematics of terrestrial and extra-terrestrial processes. Talk at the *CBC Annual Meeting*, Oslo, 6th of November, 2008.

66) **S. R. Clark**. Simulating and visualising the earth as a dynamic system. Talk given to *Valler High School Teachers*, 2008.

67) **S. K. Dahl**. A 2D patient-specific FSI assessment of mitral valve dynamics during diastolic filling. Talk at the *8th World Congress on Computational Mechanics (WCCM8)* and the *5th European Congress on Computational Methods in Applied Sciences and Engineeering (ECCOMAS 2008)*, Venice, Italy, 2008.

68) E. Berg, **B. H. Skallerud**, and K. H Holthe. Surface and embedded cracks in offshore pipelines subjected to plastic strains. Talk at the *6th International Conference on Computation of Shell and Spatial Structures*, 2008

69) **J. B. Haga**. Parallel computations and the finite element method. Invited talk at *SINTEF Information and Communication Technology*, Group for Applied Mathematics, 2008.

70) **J. E. Hake** and **G. T. Lines**. Modelling the mesoscopic length scale of EC coupling: the diadic cleft. Invited talk at the *European Conference on Mathematical and Theoretical Biology*, 2008.

71) **V. Haughton.** The Chiari I malformation from the perspective of Hans Chiari. Talk at the *Chiari Conference*, Northwest Reserach and Education Institute, 2008.

72) **V. Haughton.** The Chiari I malformation from the perspective of modern imaging. Talk at the *Chiari Conference*, Northwest Research and Education Institute, 2008.

73) **V. Haughton.** Imaging the craniovertebral junction. Talk at the *35th Annual Course on Computed Tomography and Magnetic Resonance Imaging of the Brain Rush-Presbyterian*, Chicago, 2008.

74) **L. R. Hellevik**. Wave propagation in the human fetal ductus venosus-umbilical vein bifurcation. Talk at *Reproductive Bioengineering*, Wenns im Pitztal, Austria, 2008.

75) **H. P. Langtangen,. O. Al-Khayat and A. M. Bruaset**. Numerical Python, Four day course at *University of Erlangen*, 2008.

76) **P. R. Leinan**. Fluid structure interaction modelling of pulsations in the fetal umbilical cord. Talk at the *8th World Congress on Computational Mechanics (WCCM8)*, Venice, Italy, 2008

77) **S. Linge**, **A. E. Løvgren**, **K.-A. Mardal**, and **H. P. Langtangen**. Simulating the cerebral fluid flow associated with Chiari I malformation in idealized geometries. Talk at the *CBC Workshop on High-Performance Computing and Biomedical flows*, Oslo, 2008.

78) **S. Linge**, **A. E. Løvgren**, **K.-A. Mardal**, and **H. P. Langtangen**. Simulating the cerebral fluid flow associated with Chiari I malformation in idealized geometries, Talk at the *CBC Workshop on Finite Elements for Fluids and Fluid-Structure Problems*, Oslo, Norway, 2008.

79) **S. Linge**, **A. E. Løvgren**, **K.-A. Mardal**, **V. Haughton**, and **H. P. Langtangen**. Chiari Malformation - the problem and a mathematical approach, Invited talk, Vindern Medical Center, Oslo, Norway, 2008.

80) **S. Linge**, **A. E. Løvgren**, **K.-A. Mardal**, **V. Haughton**, and **H. P. Langtangen**. Cerebrospinal fluid flow simulations - normal subjects and patients with Chiari I malformation. Talk at *CBC Workshop on Experimental, Analytical and Numerical Investigations of Blood Flow*, Oslo, 2008.

81) **S. Linge**, **A. E. Løvgren**, **K.-A. Mardal**, **V. Haughton**, and **H. P. Langtangen**. Cerebrospinal fluid flow in normal and Chiari subjects, Talk at *CBC Workshop on Robust Flow Solvers*, Oslo, 2008.

82) **A. Logg**. A symbolic engine for finite element exterior calculus, Talk at the *European Finite Element Fair 2008*, Chalmers University of Technology, Göteborg, 2008.

83) **A. Logg**. FEniCS tutorial. Talk at *CBC Annual Meeting*, Oslo, 2008.

84) **A. Logg**. A symbolic engine for finite element exterior calculus, Talk at the *Workshop on Automating the Development of Scientific Computing Software (FEniCS'08)*, Lousiana State University, Baton Rogue, USA, 2008.

85) **A. Logg**. Just-in-time compilation of finite element variational forms, Talk at the *Finite Element Circus and Rodeo*, Louisiana State University, Baton Rogue, USA, 2008.

86) **A. Logg**. FSI development at CBC, Invited speaker at the *CBC Workshop on FSI for Biomedical Applications*, Trondheim, 2008.

87) **A. Logg**. The FEniCS project, Inviteted speaker at the *Workshop on Data Structures for Finite Element and Finite Volume Computations*, Freie Universität Berlin, 2008.

88) **O. M. Lysaker**, **B. F. Nielsen**, P. Grøttum, A. Abildgaard, J. Fjeld, and K. Haugaa. Theoretical and practical aspects of the inverse problem of electrocardiography, Presented at the *Fourth International Conference "Inverse Problems: Modeling and Simulation"*, Turkey, 2008.

89) **O. M. Lysaker**, **B. F. Nielsen**, P. Grøttum, A. Abildgaard, J. Fjeld, and K. Haugaa. Computer simulations for identifying ischemic heart disease; a validation study, Presented at the *BBG-MedViz seminar at the Department of Mathematics, University of Bergen*, 2008.

90) **A. E. Løvgren**, **S. Linge**, **K.-A. Mardal**, **V. Haughton**, and **H. P. Langtangen**. CFD analysis of cerebrospinal fluid flow in the cranio-cervical region, Invited talk at the *21st Nordic Seminar on Computational Mechanics*, Trondheim, 2008.

91) **K.-A. Mardal**. Hemodynamics in the Circle of Willis, Invited talk at *Institute for Computational and Applied Mathematics, Muenster*, Germany, 2008.

92) **K.-A. Mardal**, **B. F. Nielsen**, and **M. S. Alnæs**. Two steps towards automating efficient solution of inverse problems, Invited Talk at the *FEniCS 08 Workshop*, Baton Rouge, Louisiana, 2008.

93) **K.-A. Mardal**, **K. Valen-Sendstad**, **O. C. Myklebust**, and **S. Hentschel**. Scientific computing at Simula. Invited Talk at *Workshop on Cerebral Aneurysms and Subarachnoidal Hemorrhage*, Tromsø, Norway, 2008.

94) **K.-A. Mardal**, **K. Valen-Sendstad**, **O. C. Myklebust**, and **S. Hentschel**. Blood flow computations at Simula. Invited talk at *Medical Physics*, University of Wisconsin, USA, 2008.

95) **A. McCulloch**, Systems biology and multi-scale modeling of the heart. *Pacific Biocomputing Symposium*, Plenary Lecture, Kona, Hawaii, 2008.

96) **A. McCulloch**, Systems biology and multi-scale modeling of the heart. *Seminar*, University of Washington, Department of Bioengineering, 2008.

97) **A. McCulloch**, Systems biology and multi-scale modeling of the heart. Talt at the University of Illinois Chicago, Department of Physiology and Biophysics, 2008.

98) **A. McCulloch**, Multi-scale modeling of cardiac mechanoenergetics. Talk at the *Wellcome Trust Physiome Workshop on Multi-Scale Modeling of the Heart*, Auckland, New Zealand, 2008.

99) **A. McCulloch**, Multi-scale modeling of cardiac electromechanics. Talk at the *Biomedical Engineering Math Seminar*, Worcester Polytechnic Institute, 2008.

100) **A. McCulloch**, Multi-scale modeling of cardiac electromechanics. Talk at the *Symposium on computational Physiology, Experimental Biology 2008*, San Diego, 2008.

101) **A. McCulloch**, Emerging role for multi-scale modeling in the biomedical device industry. Keynote talk at the *3rd ASME Frontiers in Biomedical Devices Conference*, Irvine, California, 2008.

102) **A. McCulloch**, Towards image-based patient-specific multi-scale modeling of the failing heart. Invited talk at the *2008 SIAM Life Sciences Conference*, Session MS35, Montreal, Canada, 2008.

103) **A. McCulloch**, Seminar: Multi-scale modeling of the heart. Talk at the *MURPA eSeminar*, Monash University, Melbourne, Australia, 2008.

104) **A. McCulloch,** Mechanosensing and mechanotransduction in the myocardium. *Seminar at the Cardiology Department*, Academic Hospital Maastricht, The Netherlands, 2008.

105) **A. McCulloch**, Multi-scale modeling of ventricular electromechanics. Invited talk at the *Cardiovascular Systems Dynamics Society XVIII Conference*, St Louis, USA, 2008.

106) **A. McCulloch**, Multi-scale modeling of the heart. Invited talk at the *NCRR P41 Directors*, National Library of Medicine, NIH, Bethesda, Maryland, USA, 2008.

107) **A. McCulloch**, Mechanobiology of normal and failing myocardium. Talk at the Physiology Department, Oxford University, Oxford, UK, 2008.

108) **A. McCulloch**, Physiome research in the USA. Invited talk at *ICT-BIO 2008*, The European Commission, Brussels, 2008.

109) **A. McCulloch**, Systems biology and multi-scale modeling of the heart. Invited talk at *ICT-BIO 2008*, The European Commission, Brussels, 2008.

110) **A. McCulloch**, Multi-scale modeling and systems biology of cardiac regulatory mechanisms. Invited talk at the *MEI International Symposium. "Physiome and Systems Biology for Integrated Life Sciences and Predictive Medicine"*, San Francisco, California, 2008.

111) **O. C. Myklebust**, **S. Hentschel**, and **K.-A. Mardal**. Patient-specific computational fluid dynamic simulations in the Circle of Willis. Invited talk at the *21st Nordic Seminar on Computational Mechanics*, Trondheim, 2008.

112) **H. Narayanan**. Toward a goal-oriented error-controlled solver for the incompressible Navier-Stokes equations, Talk at the *CBC workshop on Robust Flow Solvers*, Oslo, Norway, 2008.

113) **B. F. Nielsen, O. M. Lysaker, P. Grøttum**, **A. Tveito**, and A. Abildgaard, J. G. Fjeld, and K. Hermann Haugaa. The inverse problem of identifying ischemic heart disease, Talk at the *annual meeting of European Cardiac Simulation Group*, Bologna, Italy, 2008.

114) **B. F. Nielsen**, **O. M. Lysaker, P. Grøttum**, **A. Tveito**, and A. Abildgaard, J. G. Fjeld, and K. H. Haugaa. On the use of computer simulations for identifying ischemic heart disease; theoretical and practical aspects. Talk at the *workshop "Mathematics in Medicine/Biology"*, Centre of Mathematics for Applications, University of Oslo, 2008.

115) **B. F. Nielsen**, **O. M. Lysaker**, **P. Grøttum**, **A. Tveito**, and A. Abildgaard, J. G. Fjeld, and K. H. Haugaa. Theoretical and practical aspects of the inverse problem of electrocardiography. Talk at *Institut für Mathematik und Wissenschaftliches Rechnen, Karl Franzes Universität in Graz*, Austria. Also presented at *Institut für Numerische und Angewandte Mathematik, Westfälische Wilhelms-Universität Münster*, Germany, 2008.

116) **B. A. Pettersson Reif**. Turbulens – det siste uløste problemet i klassisk fysikk. Talk at the *POPular MAThematics (POPMAT) seminar*, University of Oslo, 2008.

117) **V. E. Prot**. Mitral valve finite element analysis using human uniaxial tensile data. Talk at the *8th World congress on computational mechanics WCCM8*, Venice, Italy, 2008.

118) **V. E. Prot** and **B. H. Skallerud**. Solid versus membrane finite elements in analysis of the mitral valve: A case study. Talk at the *6th International Conference on Computation of Shell & Spatial Structures*, 2008.

119) **A. Schroll**. Automatic calibration of depositional models: An inverse problems approach. Talk at the *33rd International Geological Congress*, Oslo, 2008.

120) **A. Schroll**. On computational mathematical modeling. Talk at a The University of Southern Danmark, 2008.

121) **A. Schroll**. Well-based calibration of geological models. Talk at *Mathematisches Forschungsinstitut Oberwolfach*, Germany, 2008.

122) R. Stresing, **M. Tutkun**, S. Lück and J. Peinke. Stochastic analysis of turbulence: n-scale and n-point correlations in homogeneous and inhomogeneous turbulent flows, Presented at the *iTi Conference on Turbulence III*, Bertinoro, Italy, 2008.

123) **K. t. Tusscher**. The role of genome and regulatory network architecture canalization in the evolution of multi-trait polymorphism and sympatric speciation. Talk at the *Centre for Ecological and Evolutionary Synthesis*, University of Oslo, 2008.

124) **K. t. Tusscher**. Genome and gene regulatory network canalization in the evolution of polymorhism and sympatric speciation. Talk at *Symposium "Celebrating 30 years of Bioinformatics"*, Utrecht University, 2008.

125) **K. t. Tusscher**. Evolutionary Biology for Non-Biologists, Talk at the *CBC annual meeting*, Oslo, 2008.

126) **M. Tutkun**, Large scale structures of high Reynolds number turbulent boundary layers. Invited talk at *the Workshop on Wall Bounded Shear Flows: Transition and Turbulence*, Cambridge University, Isaac Newton Institute for Mathematical Sciences, UK, 2008.

127) **K. Valen-Sendstad**, **A. Logg**, and **K.-A. Mardal**. Developing flow solver methodology for patient-specific simulation of hemodynamics,.Talk at the *CBC Workshop on Finite Element Methods for Fluids and Fluid-Structure Interaction*, 2008.

Workshops and Seminars

We have used the following rule of thumb to make a distinction between workshops and seminars:

Workshop: A formal event, containing several talks organized in sessions with chairmen.

Seminar: A less formal meeting between researchers which includes one or more talks with discussions.

We have in 2007 and 2008 had an emphasis on arranging workshops and seminars, with the purpose of inviting leading scientists, current collaborators and potential collaborators to CBC and discuss the state-of-the-art within several key topics of our research. This has helped us shape our research, sharpen the focus, and increase the enthusiasm. Moreover, the workshops and seminars have been an important arena for presenting research results from CBC and discuss them with international experts in the various scientific fields. Nevertheless, our aim for 2009 is to reduce the workshop and seminar activity to some extent in favour of implementing a particularly strong focus on the already planned research tasks and the release of the FEniCS software. Later, the intensity of seminars and workshop will increase again when there is need for more outreach of results and further discussions of project plans.

CBC workshops and seminars

CBC organized 12 workshops in 2008, with a total number of 110 presentations and 238 participants. Two seminars and 21 invited talks were also arranged.

Workshop on Robust Flow Solvers - January 7-9, 2008

This workshop gathered researchers involved in the Robust Flow Solver project. The purpose was to present the current state of research and identify the key problems for future research. The meeting also represented the start of the collaboration between Simula, FFI and the University of Cyprus. A particular goal of the workshop was to discover possible synergies and interactions between sub projects. As a result of the workshop, a refined research plan for the project was developed.

Total number of participants: 15
Number of different nationalities represented: 3
Total number of speakers: 13
Total number of talks: 13

First workshop in the Dispersion and Transport of Aerosol project at FFI/UCy - January 10 – 11, 2008

The purpose of this meeting was to gather people involved with the aerosol modeling project between FFI, University of Cyprus and Simula. Through eight talks with lively discussions, the aim was to refine the problem definitions and establish the right scientific focus.

Total number of participants: 14
Number of different nationalities: 4
Total number of speakers: 7
Total number of talks: 8

Workshop on Network Modeling of the Cardiovascular System - January 23, 2008

The scientific topic of this workshop was one-dimensional wave models, combined in networks, for simulating blood flow and vessel wall deformations in the cardiovascular system. Certain attention was paid to identifying promising research topics in the numerical handling of boundary conditions at internal boundaries in the network. The meeting also served as a start for a future collaboration between CBC and a group in mechanics and applied mathematics at the University of Nice.

Total number of participants: 11
Total number of guests outside of CBC: 5
Number of different nationalities represented: 3
Total number of speakers: 2
Total number of talks: 2

Seminar on Current Issues and Activities - April 15, 2008

The aim of the seminar was to discuss selected current research activities related to numerical modeling of fluid flows, with a focus on work in progress, challenges and open questions. The meeting was a follow up to the workshop on January 7-9.

Total number of participants: 13
Number of different nationalities represented: 2
Total number of speakers: 4
Total number of talks: 4

Seminar on 1D Network Models for Blood Flow: Implementational Issues - May 8, 2008

The purpose of the seminar was to precisely formulate a generic mathematical model for averaged 1D network models for blood flow with fluid-structure interaction. This was a "true workshop" with a comprehensive introductory lecture, followed by long discussions of mathematical and numerical details among the participants. The meeting was a continuation of the workshop on January 23, 2008.

Total number of participants: 3
Total number of speakers and talks: 1

Workshop on the Reduced Basis Method - May 9, 2008

This workshop gathered several leading scientists in the research on the Reduced Basis method. Speakers included Yvon Maday (Paris), Einar Rønquist (NTNU), Chris Johnson (Utah), Simone Deparis (EPFL) and Gianluigi Rozza (MIT, EPFL). The talks focused on theoretical developments as well as on a number of diverse applications. A particular purpose was to show what kind of applications that might benefit from the Reduced Basis method, and how the method is implemented in software.

Total number of participants: 39
Number of different nationalities represented: 9
Total number of speakers: 5
Total number of talks: 6

Workshop on High-Performance Computing and Biomedical Flows - May 19-21, 2008

The workshop addressed important high-performance computing (HPC) issues for biomedical flows. A certain aim was to strengthen the interaction between the CBC staff, external collaborators and international HPC experts, while also spreading useful knowledge and technologies to a broader scientific audience. Within the biomedical flows theme, particular attention was paid to 1) the flow of blood in the Circle of Willis and its consequence on aneurysm development and rupture, 2) the cerebrospinal fluid flow associated with the Chiari I malformation, and 3) the fluid-structure interaction problem in the mitral valve. Several topics within high-performance computing were presented to the audience. The HPC topics included the ACTS software collection and the PyACTS interface, component-based computational frameworks (CCA), parallel programming, and use of modern programming languages and hardware. The workshop featured internationally highly recognized speakers as well as young, promising researchers: Lutz Gross, Damian Rouson, Tony Drummond, Ben Allan, Victor Haugthon, Charles Strother, Jingfeng Jiang, Vanessa Diaz, Luca Antiga, Jørgen Isaksen and Bertil Romner.

Total number of participants: 37
Number of different nationalities represented: 10
Total number of speakers: 15
Total number of talks: 16

Workshop on Finite Element Methods for Fluids and Fluid-Structure Interaction - June 4-5, 2008

The main objective of the workshop was to present novel applications and discuss recent advances in finite element methods for fluids and fluid structure interaction, including 1) efficient discretization methods and iterative solvers, 2) adaptivity and error estimation, and 3) applications including, but not restricted to, biomedical flow. The workshop featured highly profiled international speakers along with younger talents: Wolfgang Wall, Harald van Brummelen, Stefan Turek, Claes Johnson, Johan Hoffman, Nils Svanstedt, Garth Wells, Peter Hansbo, Trond Kvamsdal, Fredrik Bengzon, Matteo Astorino, Runhild Aae Klausen, as well as PhD and postdoctoral fellows from CBC.

Total number of participants: 33
Number of different nationalities represented: 11
Total number of speakers: 14
Total number of talks: 14

Workshop on Computational Geoscience and Stochastic Simulation - Jun 06, 2008

This workshop consisted of two parts. In the first part, a series of presentations aimed to provide an overview of the current portfolio of research activities in the Computational Geoscience project. In the second part, Dr. Zenon Medina-Cetina (then at NGI/ICG, now at Texas A&M University) gave a motivation for and an introduction to Bayesian stochastic approaches to simulation. Although his examples were mainly focused on geoscientific applications, a key point was to show that the mathematical and statistical principles are applicable to all types of simulation involving data that are subject to uncertainty.

Total number of participants: 17
Number of different nationalities represented: 6
Total number of speakers: 11
Total number of talks: 12

Workshop on Simulation of Biomedical Flow Problems - June 25, 2008

The aim of this workshop was to present some recent advances in simulating biomedical flows and structures. The highlight of the workshop was a comprehensive lecture by Prof. Tom Hughes on isogeometric modeling and its recent applications, including determination of hydrodynamic noise sources in turbulent flows, stabilized and multiscale methods in Large Eddy Simulation (LES), and development of cardiovascular surgical procedures based on simulations of patient-specific models. Ongoing research in the CBC project Biomedical Flows and Structures was also presented and discussed.

Total number of participants: 18

>more

Number of different nationalities represented: 5
Total number of speakers: 4
Total number of talks: 4

Workshop on FSI for Biomedical Applications - September 8-10, 2008

The purpose of the workshop was to gather the people who collaborate, or are in the beginning phases to do so, on fluid-structure interaction problems related to blood flow. Participants from CBC groups in Oslo and Trondheim as well as researchers from the University of Ghent, Belgium, were present. The workshop was held outside Trondheim in a relaxed and stimulating atmosphere. The presentations consisted of tutorials and research talks. One aim, which was very successfully fulfilled, was to obtain increased understanding of the particular numerical challenges one faces with biomedical fluid-structure interaction problems and how these challenges can be effectively attacked.

Total number of participants: 18
Total number of guests outside of CBC: 15
Number of different nationalities represented: 5
Total number of speakers: 15
Total number of talks: 13

Workshop on Dispersion and Transport of Aerosol - September 17, 2008

This one-day workshop gathered researchers in the aerosol modeling project (between FFI, University of Cyprus and Simula) and the official Advisory Committee for this project. The objective was mainly to introduce the project to the members of the Advisory Committee get their feedback. The committee consists of people with a diverse background: Norwegian Armed Forces, Norwegian Ministry of Defence, Ullevål University Hospital, FFI, CBC/SIMULA, University of Oslo, Norwegian University of Science and Technology (NTNU), University of Cyprus, and Norwegian Meteorological Office. The workshop was held at FFI.

Total number of participants: 20
Number of different nationalities: 5
Total number of speakers: 10
Total number of talks: 11

Workshop on Experimental, Analytical and Numerical Investigations of Blood Flow - October 31, 2008

This workshop featured talks and discussions about past and future research on blood flow. First, Prof. Arnold Bertelsen and his former student Werner Filtvedt, both from the fluid mechanics group at the Dept. of Mathematics, University of Oslo, gave two comprehensive talks on their experimental, analytical and numerical investigations of blood flow in bends and bifurcations, with a particular focus on the difficulty of identifying important but small recirculating flow structures. Thereafter, CBC researchers presented their recent work and plans on simulation of specific medical problems (blood flow in the Circle of Willis, cerebrospinal fluid flow in the upper spinal canal, 1D models for network flow, and planned experiments at the hydrodynamic laboratory at the Dept. of Mathematics).

Total number of participants: 10
Total number of guests outside of CBC: 6
Number of different nationalities represented: 1
Total number of speakers: 5
Total number of talks: 5

Workshop on Current Issues and Activities in the Robust Flow Solvers Project - Dec 16, 2008

This meeting summarized achievements on developing numerical methods and software for incompressible viscous flow at CBC in 2008 and discussed plans for 2009.

Total number of participants: 9
Number of different nationalities represented: 3
Total number of speakers: 5
Total number of talks: 6

Other Activities

Media Appearances

1) Uniforum article, April 2008
In April 2008 Uniforum wrote an article about our cooperation with the University of Oslo, the Centre of Mathematics for Applications (CMA) and Simula (CBC) to reform traditional courses in mathematics intensive student programs. The reform consists of integrating numerical methods, programming and visualization in basic bachelor courses on mathematics, physics, mechanics, astrophysics, geophysics, and so on. The integration is novel, also in an international setting, and pedagogically highly non-trivial. The goal is to use computer simulations actively to develop a deeper understanding of physical sciences and mathematics, even at a very early stage in university studies.
http://wo.uio.no/as/WebObjects/avis.woa/wa/visArtikkel?id=43788&del=uniforum

2) Budtsikka TV, Asker and Bærum local TV
A report from a CBC PhD student, Omar Al-Khayat teaching science to high school students:
http://www.tvbudstikka.no/index.php?v=1284

Refereeing Activities

During 2008, employees at CBC have refereed manuscripts for:

- A*Star
- American Association for the Advancement of Science
- American Journal of Physiology
- American Heart Association
- Annals of Biomedical Engineering
- ASME Journal of Fluids Engineering
- Biophysical Journal
- Cardiovascular Research
- Cell
- Cellular and Molecular Biomechanics
- Cellular and Molecular Bioengineering
- Circulation
- Circulation Research
- Combustion Science and Technology
- Combustion Theory and Modelling
- Computer Meth Engineering and Applied Mech
- Computer Methods in Biomechanics and Biomedical Engineering
- Concurrency, Practice and Experience
- Engineering Applications of Computational Fluid Mechanics
- Engineering Fracture Mechanics
- Experimental Physiology
- Flow, Turbulence and Combustion
- Heart Rhythm
- IEEE Sensor Journal
- IEEE Transactions on Visualization and Computer Graphics
- International Journal of Heat and Fluid Flow
- International Journal of Mechanical Sciences
- International Journal of Numerical Methods in Fluids
- International Journal on Computational Science and Engineering
- Journal of the American College of Cardiology
- Journal of Biomechanical Engineering
- Journal of Cellular and Molecular Cardiology
- Journal of Computational Physics
- Journal of Clinical Investigation
- Journal of Fluid Mechanics
- Journal of Impact Engineering
- Journal of Parallel and Distributed Computing
- Medical Research Council, New Zealand
- National Institutes of Health
- National Science Foundation
- New Zealand Health Research Council
- Nonlinear Analysis: Modelling and Control
- Parallel Computing
- Parallel Processing Letters
- Philosophical Transactions of the Royal Society
- Physics of Fluids
- Physiological Measurement
- PLoS Computational Biology
- Progress in Biophysics and Molecular Biology
- Proceedings of the National Academy of Sciences
- The Royal Society (London)
- SIAM Journal on Scientific Computing
- Systems and Synthetic Biology
- Ultrasound in Obstetrics and Gynecology

Editorial Boards

Employees of the center are on the following editorial boards:

K. H. Karlsen:
1) Advances in Applied Mathematics and Mechanics (AAMM)
2) Advances in Numerical Analysis (ANA)
3) Journal of Hyperbolic Differential Equations (JHDE)
4) Networks and Heterogeneous Media (NHM)
5) SIAM Journal on Numerical Analysis (SINUM)

H. P. Langtangen:
1) Advances in Water Resources
2) BIT Numerical Mathematics
3) International Journal of Applied Mathematics & Computational Sciences (IJAMCS)
4) International Journal of Computational Science and Engineering
5) International Journal of Oceans and Oceanography (IJOO)
6) Mathematical Modelling and Applied Computing (MMAC)
7) SIAM Journal on Scientific Computing

A. McCulloch:
1) ASME Journal of Biomechanical Engineering
2) Cellular and Molecular Bioengineering
3) Computer Methods in Biomechanics and Biomedical Engineering
4) Drug Discovery Today: Disease Models *(Editor in Chief)*

5) Medical and Biological Engineering and Computing
6) PLoS Computational Biology
7) Systems and Synthetic Biology

B. A. P. Reif:

1) International Journal of Heat and Fluid Flow, Elsevier Science

B. Skallerud:

1) International Journal of Applied Mechanics

J. Sundnes:

1) Simulation modeling practice and theory, International Journal of the Federation of European Simulation Societies (EUROSIM)

A. Tveito:

1. Computing and Visualization in Science
2. SIAM Journal on Scientific Computing

Conference Committees

1) **H. P. Langtangen:** Web Based Distributed Computing track of the International Conference on Distributed Computing (ICDCS), June 17-20, 2008
2) **K. H. Karlsen:** 12th International Conference on Hyperbolic Problems: Theory, Numerics, Applications(HYP2008), June 9 – 13, 2008

Organization of Minisymposiums at Conferences

1) **X. Cai**. Minisymposium on Advanced Computing in Geosciences at PARA2008, May 14-15, 2008

Outreach

1) **O. al-Khayat:** Teaching science to high school students: http://www.tvbudstikka.no/index.php?v=1284

Releases of Software Packages

In 2008, we released a new stable version of the UFC interface, UFC 1.1. In addition, the following software projects were developed significantly:

- Dolfin: 0.7, 0.8
- FFC: 0.4, 0.5
- Instant: 0.9
- Viper: 0.2, 0.3, 0.4
- SyFi: 0.5

In 2009, we expect several of these projects to be released in stable versions.

List of International Guests in 2008

In 2008 CBC had 54 international guests with 14 different nationalities.
Norwegian visitors are not listed, but count more than 35.

Period	Name	Affiliation	Nationality
November 12-14	Jan Morup Jorgensen	University of Copenhagen	Danish
October 21	Dr. Lina von Sydow	University of Uppsala	Swedish
October 19-November 23	Dr. Joseph Werne	University of Colorado, Boulder	American
September 28-29	Prof. Strauros Kassinos	University of Cyprus	Cyprian
September 25	Prof. Gernot Plank	Medizinische Universität Graz	Austrian
August 28-October 9	Andy Terrel	University of Chicago	American
August 28	Prof. Wen Shen	Pennsylvania State University	Italian
August 27-28	Sven-Erik Ekström	University of Uppsala	Swedish
August 27	Eddie Wadbrod	University of Uppsala	Swedish
August 27	Prof. Martin Berggren	University of Umeå	Swedish
August 4-10	Prof. Robert C. Kirby	University of Texas	American
August 3-10	Dr. Dmitry Karpeev	Argonne National Laboratory	American
August 3-10	Dr. Matthew Knepley	Argonne National Laboratory	American
June 25	Dr. Tom Hughes	University of Texas	American
June 25	Dr. Yuri Bazilevs	University of California, San Diego	American
June 6, 12	Dr. Zenon Medina-Cetina	NGI - Norwegian Geotechnical Institute	Mexican
June 5	Prof. StefanTurek	Technische Universität Dortmund	German
June 4-5	Prof. Claes Johnson	KTH - Royal Institute of Technology	Swedish
June 4-5	Dag Lindbo	KTH - Royal Institute of Technology	Swedish
June 4-5	Dr. Dominik Szczerba	ETH - Swiss Federal Institute of Technology	Polish
June 4-5	Fredrik Bengzon	Umeå University	Swedish
June 4-5	Dr. Harald van Brummelen	Delft University of Technology	Dutch
June 4-5	Martin Larsson	NTNU - Norwegian University of Science and Technology	Swedish
June 4-5	Matteo Astorino	INRIA - The French Nat. Institute for Research in Computer Science and Control	Italian
June 4-5	Prof. Nils E. M. Svanstedt	University of Gothenburg	Swedish
June 4-5	Prof. Peter Hansbo	Chalmers University of Technology	Swedish
June 4-5	Prof. Wolfgang Wall	Technische Universität München	Swiss
June 4	Dr. Garth Wells	University of Cambridge	Australian
June 4	Dr. Johan Hoffman	KTH – Royal Institute of Technology	Swedish
June 2	Dr. Qin Xin	Simula Research Laboratory	Chinese
May 19-21	Dr. Cesar Pichardo	Unilever R&D Colsworth, UK	Venezuelan
May 19-21	Prof. Charles Strother	University of Wisconsin	American
May 19-21	Dr. Jinfeng Jiang	University of Wisconsin	American
May 19-21	Dr. Luca Antiga	Mario Negri Institute for Pharmacological Research, Ranica (BG)	Italian
May 19-21	Dr. Lutz Gross	University of Queensland	German
May 19-21	Dr. Vanessa Diaz	University College London	Italian
May 19	Dr. Ben Allan	Sandia National Lab, USA	American
May 19	Dr. Damian Rouson	Sandia National Lab, USA	American
May 19	Dr. Tony Drummond	Lawrence Berkeley National Lab, USA	American
June 2-May 19	Yvon Halwachs	Kalkulo	French
May 9	Prof. Yvonne Maday	UPMC – University Paris VI	French

May 8-13	Dr. Rozza Gianluigi	MIT - Massachusetts Institute of Technology, Boston, US; EPFL - Ecole Polytechnique Federale De Lausanne, Switzerland	Italian
May 6-10	Dr. Simone Deparis	EPFL (Ecole Polytechnique Federale De Lausanne, Switzerland)	Swiss
April 24	Prof. Hans-Peter Remme	Munich University	German
April 10-11	Mary M. Maleckar	Jon Hapkins University	American
April 9-11	Pan Li	University of Leeds	Chinese
March 4-6	Prof. Gerhard Zumbusch	Friedrich-Schiller-Universität Jena	German
January 25	Samuel Wall	University of California, Berkely	American
January 23	Prof. Didier Clamond	CNRS - University of Nice	French
January 22-25	Prof. Mederic Argentina	CNRS – University of Nice	French
January 22-25	Dr. Richard Pasquetti	CNRS – University of Nice	French
January 22-24	Prof. Frans van de Vosse	Eindhoven University of Technology	Dutch
January 22-24	Dr. Francois Gallarie	CNRS – University of Nice	French
January 21	Dr. Hans Ekkehard Plesser	Norwegian University of Life Sciences	German

Norwegian Centre of Excellence

EXPERT EVALUATIONS OF CBCs APPLICATION FOR CoE

«The international researchers associated with the proposed center is a list of some of the top computational scientists and bioengineers in the world.»

«This is an excellent proposal with an outstanding set of researchers with long track records of conducting excellent research and software.»

«I would say the main criterion for the success of this project is if the software is actually used by scientists in the field.»

«Their plans for publication of research results is quite novel in that they have an unusual record for producing books. This is a good thing, and something others should emulate.»

«The group making this proposal is one of the leading groups in the world involved in developing computational middleware and numerical methods and in applying these tools to solve scientific problems.»

«Simply outstanding. It will provide great benefit to Norway and to international scientific culture.»

«It is clear that the center will be recognized world-wide as "the place to be" in computational science.»

«There is potential for significant impact beyond the scope of the proposal.»

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