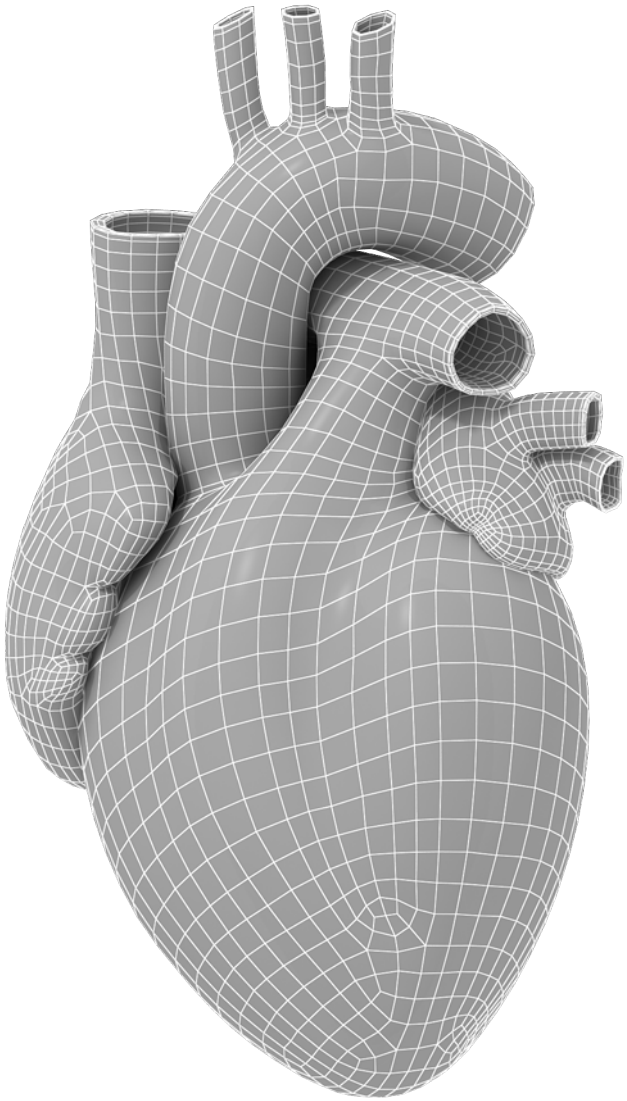
Norwegian Centre of Excellence

# Center for Biomedical Computing



## Annual report 2007

# Word from the Director

In October 2005, the Scientific Computing department at Simula Research Laboratory submitted a proposal for a ten-year Center of Excellence project financed by the Research Council of Norway. The proposal made it through the pre-qualification, and a revised version was submitted in the middle of 2006. At the end of 2006, our proposal was successfully awarded with a Center of Excellence. The competition was tough: 8 out of 98 submissions were funded. As a direct consequence of preparing and revising the proposal, we became very excited by the new research tasks ahead of us, and this led to a gradual shift in research focus towards the topics of the proposal. Many of the center's initial research results were therefore produced before the official start of the center on April 1, 2007. This fact helped to make 2007 a very productive year.

The original proposal, named "Software Components for Biomedical Flows", contained a very focused research project on software and numerical methods with applications to challenging flow problems in the human body. We already had a strong activity at Simula on software and numerical methods, mainly directed towards two application areas: heart electrophysiology and hydrocarbon exploration. We soon realized that the new research topics in the Center of Excellence proposal and the existing research projects at Simula could mutually benefit from a tighter integration. We therefore decided to include the existing Simula projects in the center and introduce a simpler name: Center for Biomedical Computing, abbreviated CBC. Two projects related to heart electrophysiology and mechanics were integrated in August 2007, while the basic research parts of the hydrocarbon exploration projects are to be fully integrated in 2008.

CBC aims at doing high-quality fundamental research, but all of our activity has a future goal of producing useful results for the society or industry. The research on software and numerical methods is application driven, i.e., the topics we dive into must be important for solving applied problems of significant interest in biomedicine or geoscience. Occasionally, we may also address other application areas when our development of numerical methods and software can benefit from the application's demands and our solution methodology can contribute to new insight in the applied problem. However, the set of applied problems we concentrate on is very limited and chosen in close collaboration with application experts, typically medical doctors, mechanical engineers, and geoscientists in our case. It is of particular importance that the chosen applied problems fit our specialized bag of tools within mathematics, continuum mechanics, numerical methods, and scientific software. On our way to solving the applied problems, our tools must normally be further developed and expanded, and the results from this research are regularly published in leading archival journals. New insight into applied problems, based on a utilization of our tools, will be published in medical and geoscience journals, co-authored with experts in those fields. Such multi-disciplinary research is challenging to produce, but we have some very encouraging results in 2007 both towards medicine and geoscience, and one medical paper has already been published.

Because CBC is part of a well-established and efficient research organization (Simula), the administrative burden of establishing the center was minimized. Turning a substantial budget increase into high-quality research takes time and effort, and much of the activity in the first year has been centered around start-up activities like refinement of the research plan, exploring new scientific fields, establishing new collaboration partners, recruitment, and implementing a new organizational structure. This activity is described in more detail in the next section "Establishing CBC".

Finally I will mention the two most substantial results achieved in 2007. Firstly, a very prestigious Young Outstanding Investigator Award (YFF) from the Research Council of Norway, was given to our project leader Dr. Anders Logg. Secondly, we were able to attract and secure a significant external funding of CBC from new partners that have decided to join the projects. We are of course very pleased with the fact that the original budget for 2007 has almost doubled and that only one-third of the funding of CBC now comes from the Center of Excellence grant.

*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.*

# Establishing CBC

As described in this section, establishing CBC was a smooth process, much due to the support and existing structure of our host institution. Below we elaborate on the key activities concerning creating CBC: refinement of the research plan, expanding the center, organization of the center, the relation to our host institution, the Scientific Advisory Board, and the relation to the Simula School of Research and Innovation.

## Refining the Research Plan

Our proposal presents a natural sequence of research topics. First, we develop some generic software components. Second, we use these components in the design of more robust numerical methods for fluid flow, and third, we use the methods to attack some challenging biomedical flow problems. During the first year of operation we have made no substantial changes to this plan, except that we will run the three activities (software, numerics, and bioflow applications) more in parallel. This choice was motivated by the need for obtaining more insight into the biomedical issues at an early stage, so that the development of numerical methods and software can be better guided in the right direction. The allocation of resources between the projects was therefore adjusted, but the total allocation of funds over a ten-year period is approximately unchanged.

## Expanding the Center

A more substantial change to the original plan is that we have expanded the original focus of the center, to include the established biologically oriented research topics at Simula. These topics, mainly concerned with modeling the electrical activity of the heart, have gained significant experience with biomedical modeling, large-scale parallel computing, robust numerics, inverse problems, highly heterogeneous media with complicated constitutive laws, and new software tools for solving partial differential equations. Another project, working with hydrocarbon exploration, has gathered much experience with industrial collaboration and professional software development, and many of the mentioned scientific topics also arise here: heterogeneous media with complicated constitutive laws, large-scale parallel computing, robust numerics, and inverse problems. Knowledge about all these topics is very useful for the proposed activities toward biomedical flows. It is therefore natural to integrate the existing projects in the new center and implement a close collaboration on the topics of mathematics, numerical methods, continuum mechanical modeling, and software development. The interaction with external application experts (geoscientists, mechanical engineers, medical doctors), will of course differ among the projects. However, the synergy we expect is that solutions found in a geoproblem can have novel applications in biomedicine and vice versa.

Expanding the scope and funding of the initial research plan for the center requires some careful considerations and administrative adjustments. Two projects on the electrophysiology and mechanics of the heart were integrated from August 2007, while the research activities in geoscience will be formally included from 2008 and described in more detail in next year's annual report.

In addition to expanding the center at Simula, we also saw a geographical expansion of CBC in 2007. In the beginning of the year, we established a very promising relation to the Biomechanics group at the Norwegian University of Science and Technology (NTNU) in Trondheim. This group has a firm solid and fluid mechanics foundation and several years of experience with biomechanics. This is a very valuable complement to the competence at Simula. The group therefore became CBC's first node[1]. At present, the group consists of two professors: Bjørn Skallerud (head) and Leif Rune Hellevik; two PhD students: Paul Roger Leinan and Victorien Prot; and one research trainee: Sigrid K. Dahl. We funded one of the students in the group, and through this financial support we managed to get another student funded by NTNU. We hope to repeat such mutual funding in the future to increase the activity on bioflows in CBC. The work at the biomechanics node is presented in detail later in the report.

## Organization

As described in the proposal for the Center of Excellence, the research is organized into projects having distinct goals and research plans, with highly integrated research topics and close collaboration between the projects. The center is managed by Prof. Hans Petter Langtangen, with Dr. Joakim Sundnes as deputy leader and Tom Atkinson as administrative manager. After including Simula's two heart modeling projects (4 and 5 in the list below) and the geoscience project (6 in the list below), CBC will feature six projects:

1) Computational Middleware, with project leader Ola Skavhaug
2) Robust Flow Solvers, with project leader Anders Logg
3) Biomedical Flows, with project leader Kent-André Mardal
4) Cardiac Computations, with project leader Glenn T. Lines
5) Inverse Problems, with project leader Bjørn Fredrik Nielsen
6) Computational Geoscience, with project leader Are Magnus Bruaset (from 2008)

The first three projects are new activities that were described in the proposal, while the last three are well-established research projects that have been in operation for several years. As indicated in the proposal, each of the three new projects has assigned an experi-

1. *A node is an external partner that collaborates with CBC in a joint project where both partners contribute with resources. Resources will normally consist of direct or indirect financial support (personnel, equipment, and infrastructure). At least one representative from the external partner must dedicate some or all of the research capacity into the project. In order to ensure close and real collaboration, the participants from a node should regularly spend periods at CBC during the project period. The node must provide an additional benefit to CBC that could not be gained by establishing a similar project at CBC.*

enced Principal Investigator (PI), who supervises the research and the strategic planning. Hans Petter Langtangen serves this role for Computational Middleware; Prof. Mats Larson, Umeå University, for Robust Flow Solvers; and Prof. Andrew McCulloch, University of California at San Diego for Biomedical Flows. The project leaders have the day-to-day responsibility of running the research projects, while the PIs are responsible for the research direction and strategic decisions. We have chosen to employ young and promising researchers as project leaders in the new projects, supported by an experienced PI, in order to train the young researchers in research management. According to our experience, this is a good way to recruit and develop young talented researchers, by giving them opportunities that would be difficult for them to obtain if they were to compete with more established researchers.

Although the center is organized into separate research projects, the projects are tightly integrated and to a large extent inter-dependent. Efficient communication between the projects, and in particular between the project leaders, is therefore crucial. To ensure the necessary cooperation and sharing of experiences and results, the center managers have weekly meetings with the project leaders and senior researchers. In addition, some of the project leaders and key researchers work in multiple projects. This helps to increase the flow of technology and information in the organization, and contributes to consolidate a common understanding for CBC's focused activity and direction.

## Relation to the Host Organization

CBC is hosted by the Simula Research Laboratory, which is a research company established in 2001 and located at the old airport at Fornebu outside Oslo. Simula conducts basic research in three areas: Network and Distributed Systems, Scientific Computing, and Software Engineering. CBC belongs to the Scientific Computing department. The unique feature of Simula is that it performs steered, government funded, basic research, but with corporate-style management. This has led to very focused, large, long-term research projects supported by an excellent administrative infrastructure. Simula is evaluated every five years, and successful evaluations are necessary to prolong government funding.

It is our experience that most of the other Centers of Excellence usually need quite a substantial effort to negotiate with the host institution to find appropriate office space and solve other administrative matters. Centers must also establish a scientific advisory board and organize the people and research into groups with scientific leaders. In a university infrastructure such tasks may be challenging. This has not been the case for CBC, because our host institution was already run as a very effective research organization where all the mentioned topics were taken care of. CBC greatly acknowledges the attitude and professionalism of its host institution. Simula strongly supports CBC and provides all the administrative and scientific assistance that the center needs, including additional office space. Further, as all the research at Simula is organized in projects with project leaders, CBC benefits from this experience in organizing its scientific activities.

## The Scientific Advisory Board

It is of great value for a Center of Excellence to have a board or advisory group consisting of experienced researchers who are among the international leaders within their fields. Since Simula already has a Scientific Advisory Board (SAB), and because Simula over the last years has continuously improved the composition of and the interaction with this board, we have also chosen to employ this board for advising CBC, instead of establishing a separate advisory unit. The SAB is appointed by Simula's Board of Directors to provide focused professional advice on Simula's and CBC's operations. The SAB currently consists of five internationally recognized researchers, who together cover all the scientific fields represented at Simula:

- Prof. Barbara Kitchenham, Keele University
- Prof. Andrew McCulloch, University of California at San Diego
- Prof. Klara Nahrstedt, University of Illinois at Urbana-Champaign
- Prof. Torger Reve, Norwegian School of Management
- Prof. Lars Walløe, University of Oslo

The SAB meets every 18 months at Simula Research Laboratory. The areas of the CBC are well covered by Andrew McCulloch and Lars Walløe, who provide the biomedical expertise necessary to supplement the computational knowledge within CBC. The SAB meeting in June 2007 provided valuable advice on establishing the center and prioritizing the planned research tasks. Although the services of the SAB at present seem completely satisfactory for CBC, it is possible that the SAB will be extended with an additional member covering the relevant scientific fields. It is also possible that the SAB members most closely connected to CBC may meet more frequently if necessary.

### Simula School of Research and Innovation AS (SSRI)

CBC has entered into a partnership with SSRI regarding the education of our research trainees, PhD students and postdocs. SSRI organizes the research education at Simula. Whereas the PhD candidates and postdocs are employed in SSRI, the local supervisors are usually found in the basic research units, including CBC. SSRI serves the purpose of streamlining the educational process, such that both students and supervisors can concentrate on the scientific challenges. SSRI's role also includes close monitoring of the relationship between students and supervisors in order to diagnose and remedy potential problems at an early stage. The overall goal is to make sure that the PhD candidates graduate within their allocated project period and deliver high-quality results.

The Simula School of Research and Innovation (SSRI) was established as a limited company in May 2008. SSRI is owned by Simula Research Laboratory (56%), StatoilHydro (21%), the municipality of Bærum (14%), Telenor (7%), SINTEF (1%) and the Norwegian Computing Center (1%). The four largest owners provide substantial funding for research trainee, PhD, and postdoc positions in addition to SSRI's public funding.
The primary goal for SSRI is to provide optimal conditions for research education at an internationally high quality level. SSRI helps PhD candidates to successfully complete their degrees in time, and supports the postdocs on their way towards a career in academic or industrial research.

As a qualifying step before beginning PhD studies, SSRI offers the opportunity of one-year contracts as a research trainee. This type of position provides a unique opportunity for both the student and Simula to ensure that a PhD education is the right track for the person in question. By being exposed to a variety of research tasks in the Simula environment, the individual candidate acquires highly relevant experience and will be productive from the very beginning when entering a PhD position. SSRI is in the process of establishing collaborations with relevant industrial and academic partners; research trainees and PhD candidates are encouraged to spend periods in these environments, from just a couple of weeks to several months.

By affiliating the PhD students and postdocs working on CBC projects with SSRI, these persons 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 research trainee, PhD and postdoc positions for projects that share a common scientific base with activities in CBC. In particular, in 2007 SSRI funded three research trainees and one postdoc who have been dedicated to CBC projects. Moreover, SSRI currently receives external funding from industry for two PhD candidates, one postdoc and one researcher working on topics that will be fully integrated in CBC in 2008. SSRI intends to increase the size of these shared activities with one more postdoc position in 2008.

## People, Recruitment, and Gender Issues

Recruiting new personnel has been a key activity for CBC in 2007. An important action was to hire Tom Atkinson as administrative manager for the center. Any Center of Excellence needs a highly competent administrative staff, and Tom works closely with the administrative unit at Simula and the other managers in the center. CBC greatly appreciates that Simula has a clear policy of decreasing the administrative burden on the research staff to ensure that researchers spend as much time as possible on research.

It is challenging to turn a significantly increased budget into research within a few months. Accordingly, we defined several smaller research and review projects in order to offer short-term postdoc contracts. These short-term projects were used to evaluate potentially new employees and research topics. By the end of 2007 most of these short-term projects have either been terminated or turned into activities with a longer perspective.

Simula Research Laboratory, and more recently SSRI, has been a successful equal opportunities employer, recruiting a significant proportion of women and people with diverse backgrounds. Although at this point we have few women in senior scientific positions at Simula, we continuously seek to recruit qualified female researchers in the relevant scientific fields.

In 2007, three out of seven new PhD students and research trainees were women. Recently, we also employed Dr. Kirsten ten Tusscher, who is a very promising young scientist in biomedical computing. Tusscher will start at Simula on June 1, 2008, and establish a new project on modeling cardiac arrhythmias and evolutionary processes.

# Scientific Activitities

The scientific activities in 2007 were focused on establishing the new research fields, recruiting new researchers, and integrating existing Simula projects into the new center. However, since we geared the activity towards the areas of the proposal already from 2005, the scientific activity has been at a high level in all projects throughout 2007. Below we provide a brief summary of the center's activities in each of the current research projects this year.

## The Research Projects

### Computational Middleware

*Project leader: Ola Skavhaug*
*Principal investigator: Hans Petter Langtangen*

The purpose of the Computational Middleware project is to develop methods and software for efficient numerical solution of partial differential equations in general, and biomedical applications in particular.

When studying real-life biomedical processes by numerical simulation, the amount of computer power needed is almost unlimited. Hence, the computational efficiency of the underlying software frameworks greatly affects the range of problems that is possible to study. Additionally, as biomedical problems are often extremely complicated, the basic components of software frameworks must be generic enough to be applicable to a wide range of problems. For instance, a realistic simulation of a heart beat might involve coupling models for the electrical pulse through the heart, the elasticity of the heart when contracting and expanding, and the partially turbulent blood flow in the heart chambers. One of the major challenges in the Computational Middleware project is to develop software components that combine generality and efficiency.

The activity of the Computational Middleware project spans both academic research and pure software development. The research topics cover parallel computing, scientific software engineering, the design of middleware interfaces, and the design of interfaces for coupling complete simulators. In addition, we develop and maintain a series of software projects. Some of the most important ones that experienced significant improvements in 2007 are listed below.

- FEniCS: A collection of tools with the purpose of automating computational mathematical modeling. Several international institutions contribute to this software collection (www.fenics.org).
- FFC: A compiler that translates high-level descriptions of finite element variational forms into efficient C++ code (part of FEniCS).
- SyFi: An alternative to FFC based on symbolic computing of finite elements (part of FEniCS).
- DOLFIN: A modern C++ library for the generic tasks in finite element computations (part of FEniCS).
- PyCC: A problem solving environment for solving partial differential equations by finite element methods. PyCC is based on SyFi and DOLFIN.
- F2PY: A tool for convenient coupling of Python and Fortran code.
- Instant: A tool for inlining efficient C/C++ code in Python programs.
- UFC: An interface specification for the coupling of general finite element libraries to problem-specific descriptions of a finite element problem (part of FEniCS).
- Swiginac: A tool that makes it possible for a Python program to conveniently access the GiNaC C++ package for symbolic computations (swiginac.berlios.de).
- SciTools: A set of tools for enhancing Matlab-style computing and visualization with the powerful Python platform (scitools.googlecode.com).
- Viper: A tool based on VTK for convenient visualization of scalar fields.

The staff in the Computational Middleware project consists of both researchers and developers, reflecting the dual nature of scientific software development and engineering.

The collaboration with Prof. Scott Baden, University of California at San Diego, was formally started in 2007. Prof. Baden paid several visits to CBC, and gave lectures at our workshops in June and October. During Prof. Baden's visits and through later electronic communications, we have planned in more detail the research on high-performance and parallel computing. For example, a CBC-funded PhD student working in Prof. Baden's group started implementing a set of our most frequently used computational kernels on the IBM Cell processor (a multicore architecture).

### Robust Flow Solvers

*Project leader: Anders Logg*
*Principal investigator: Mats G. Larson*

The goal of the Robust Flow Solver project is to develop robust and efficient solvers for fluid flow and fluid-structure interaction. The solvers are based on the software developed by the Computational Middleware project and used as the basic building blocks for simulating complex flow problems in the Biomedical Flows project. The key to building such robust solvers is a posteriori error estimation techniques and adaptive algorithms that automatically tune the local resolution in the individual solvers to achieve overall accuracy.

As part of the project, we have developed a framework for a posteriori error estimation and adaptive algorithms for coupled multiphysics solvers. The framework enables quantification of the influence of errors in an individual solver on a given user provided output quantity. Applications investigated so far include coupled flow-transport problems and thermoelasticity. We are currently extending the framework to fluid-structure interaction.

In another activity tied to this project, we investigate how to apply the reduced basis method to the modeling of hierarchical flow systems. Together with external collaborators, the geometry of the

computational domain has been introduced as a parameter to allow efficient computation of flow in a series of pipes and bifurcations by coupling precomputed basis functions on subproblems. The long term goal is to apply the methodology to the full three-dimensional, time-dependent Navier-Stokes equations and fluid-structure interaction problems encountered in bioflows.

The achievements of the project also obtained significant recognition from the scientific community in 2007. Project leader Anders Logg received one of the prestigious Outstanding Young Investigator (YFF) grants from the Research Council of Norway for the project Automation of Error Control with Application to Fluid-Structure Interaction in Biomedicine. The project will run over four years and interact closely with the Robust Flow Solver project. Logg also published the paper "Automating the Finite Element Method" in Archives of Computational Mechanics and Engineering. This is an exclusive journal which publishes a very limited set of papers per year, and papers are normally published following direct invitation from the editor. Logg's contribution explains much of the philosophy behind the software and numerical methods initiatives in CBC.

## Biomedical Flows

*Project leader: Kent-André Mardal*
*Principal investigator: Andrew McCulloch*

The purpose of the Biomedical Flows project is to apply the numerical methods and software developed by the Robust Flow Solvers and the Computational Middleware projects to selected biomedical flow problems. The problems should have a potential for improving the understanding of biomedical processes or help to develop new medical technology. Our efforts in this project have in 2007 been concentrated on three selected projects: the blood flow in the Circle of Willis, the flow of cerebrospinal fluid in the head and the spine, and the fluid-structure interaction in the left ventricle/mitral valve region.

The first project deals with the differences in blood flow caused by anatomical variations of the blood vessels in the Circle of Willis, and the blood flow's role in the development and rupture of aneurysms. Together with neurosurgeons in Norway, Denmark, and Australia, CBC researchers published a study of the blood flow in the complete Circle of Willis in the prestigious medical journal Stroke. The results achieved public attention in 12 Norwegian newspapers. Doing such simulations is clearly interesting for the medical community; our collaborator Jørgen Isaksen got the "Young Neurosurgeon Award Competition" award at the "Scandinavian Neurosugical Society 59th Annual Congress" in Helsinki, May 31 - June 3, 2007 for a similar study, in a work with Trond Kvamsdal from SINTEF/NTNU (who was partially funded by CBC for this research). This latter study is also accepted for publication in Stroke.

The mentioned works have been extended in two directions at CBC. First, we have conducted a patient-specific simulation of bypass surgery. During this project we have also established a collaboration with Luca Antiga (Italy), the author of a state-of-the-art library VMTK for generation of blood vessel meshes from medical images. Second, we have investigated the influence of the amount of coil in aneurysms on the hemodynamic forces on the vessel wall using synthetic geometries. Our collaborating neurosurgeons are excited by the novel work and wish to extend the patient studies.

Predicting aneurysms development and rupture in the Circle of Willis is today done by considering medical images of the anatomy and risk factors such as hyper-tension, alcohol and smoking. Simulations of the blood flow have the potential of improving the predictions. We are very satisfied that our simulation studies are already published in a leading medical archival journal.

In another bioflow application we address the flow of cerebrospinal fluid in the head and spine to gain an understanding of syrinx development for patients with the Chiari malformation. This project is motivated by our collaborating medical doctor, Prof. Victor Haughton, University of Wisconsin, and his wish for a better understanding of how variations in cerebrospinal fluid flow cause the syrinx development, the need for identifying critical flow, and most importantly, the potential for simulating how healthy flow can be restored in the best possible way through surgical intervention. In the fall of 2007 we started a study of this flow problem, together with Prof. Haughton.

Finally, the Biomechanics group, which constitutes a CBC node at the Norwegian University of Science and Technology (NTNU), has continued their work on modeling of fluid structure interaction problems in the left ventricle/mitral valve region and in blood vessel networks. This work is described in more detail later in the report.

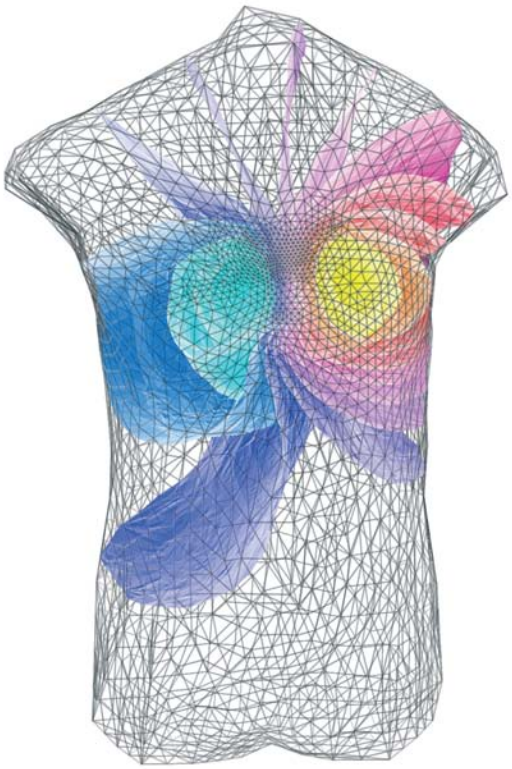
## Cardiac Computations

*Project leader: Glenn Terje Lines*

In the Cardiac Computations project we use mathematical modeling and simulation to study the heart. Although the heart is a well studied organ there are many unsettled questions. For example, what triggers fibrillation and why does defibrillation work? The system under study is so complex that it is seldom possible to deduce macroscopic consequences from microscopic changes, such as the likelihood for fibrillation given an up-regulation of a specific ionic channel. Using simulations it is possible to compute such consequences.

To simulate a beating heart, a detailed mathematical model is needed. It must include a description of the way the electrical signal propagates throughout the muscle, how - at the cellular level - this signal gives rise to a cascade of events that ends with cell contraction, and finally, how this contraction deforms the heart mechanically in an efficient way to carry out the pumping function.

Such a model will obviously be very complex, thus raising 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 figure shows a snapshot of the electrical potential generated by the heart.»*

The simulation software can be used to study a broad range of phenomena. Together with our medical partners we have selected a few target applications. With Haukeland University Hospital we study how to treat atrial fibrillation using radio frequency ablation. Prior to surgery the electrical activity of the patient's heart is mapped using a catheter. This information is rather sparse, and it is not always easy to deduce the activation pattern from it. We have developed an algorithm that combines measurements and simulations in order to improve the information content. The next phase of this project will be to optimize the method for patient specific cases. We will also do studies on the role of spatial heterogeneity of cell types in the atria, in terms of initiation and termination of fibrillation.

With Ullevål University Hospital we study how muscle cells in the heart behave during heart failure. We focus on sub-cellular calcium signaling and how this is disrupted in failing heart cells. Simulating diffusion in these small spaces, and at small concentrations, raises methodological questions. It has been argued that the diffusing particles should be tracked individually, but we have established that for a large class of problems it is justified to use a continuum description. This is a great advantage as it allows for simpler and more efficient code. The next goal in this project is to develop a simulator that incorporates all important features of the local cellular environment, including ionic channels and pumps, buffers, electrical field strength, and geometrical structure.

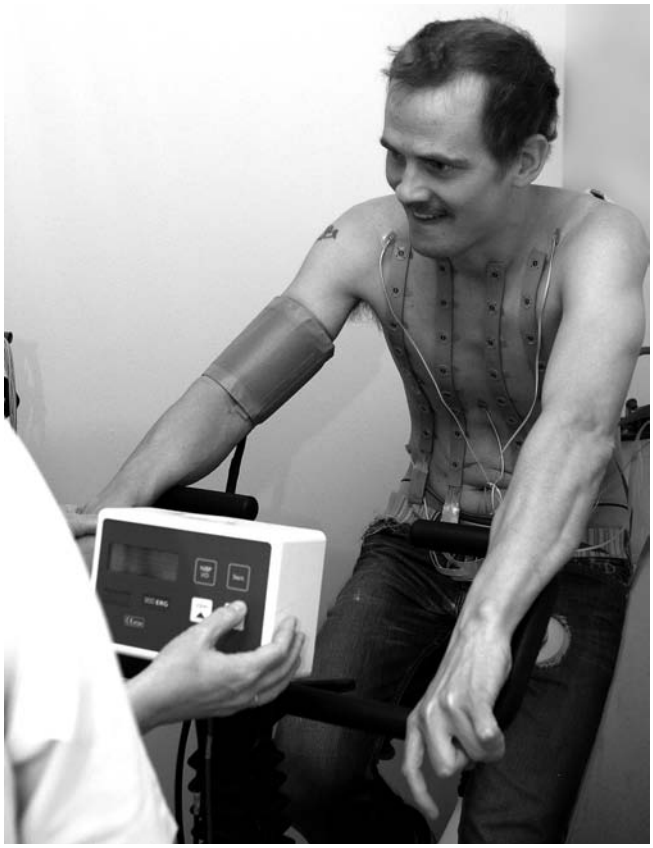
The most recent application is low voltage defibrillation, where the challenge is to design an implantable device capable of terminating an arrhythmia by applying considerable less energy than used today. The first goal here will be to build a model that can realistically reproduce ventricular fibrillation and defibrillation.

In 2007 the ties with international groups have been strengthened. For example, the project group has been involved in two different EU applications for the ICT program Virtual Physiological Human. The group also got its second paper accepted in the prestigious Biophysical Journal.

## Inverse Problems

*Project leader: Bjørn Fredrik Nielsen*

The purpose of the Inverse Problems project at Simula is to analyze and solve inverse problems arising in connection with ECG (electrocardiogram) recordings. More specifically, our main efforts address the following challenge: Is it possible to use mathematics, computers, and ECG recordings to determine the size and location of a myocardial ischemia[2] ?



*«Modern multi-channel ECG recording devices play an important role in the Inverse Problems project at Simula. The picture shows Marius Lysaker, one of our key researchers, testing the equipment.»*

2. *An ischemia is a reversible precursor of heart infarction.*

In view of the number of people suffering from this disease, this is certainly a very important problem. The mathematical models we use are based on refined results from many years of research in the Cardiac Computations project. In 2007, we improved our mathematical, computational, and biological insight and performed simulations with synthetic data. Furthermore, our collaboration with Rikshospitalet HF was intensified, as we want to test our schemes on real world data. More precisely, ECGs and geometrical information will be recorded from a number of patients. Thereafter, the project staff will run the developed algorithms with these data and explore the performance, i.e., check if it is possible to identify the position and size of potential ischemic regions. The project group and Prof. Martin Burger at the University of Münster have successfully applied for funding to cooperate in 2008.

Six journal articles were published in 2007 demonstrating our research proficiency. The project leader Bjørn Fredrik Nielsen gave a talk at the International Congress on Industrial and Applied Mathematics (ICIAM) conference and co-wrote an article "Can inverse problems tell you the condition of your heart?", published in the "Zurich Intelligencer" (by Springer), which was distributed to over 3000 participants at that conference. ICIAM is the largest and leading conference for applied and industrial mathematics, and an article in the "Zurich Intelligencer" gives attention of a magnitude that is rarely experienced by Scientific Computing researchers. Bjørn Fredrik Nielsen also received the Simula Research Award in December 2007.

### Computational Geoscience

*Project leader: Are Magnus Bruaset*

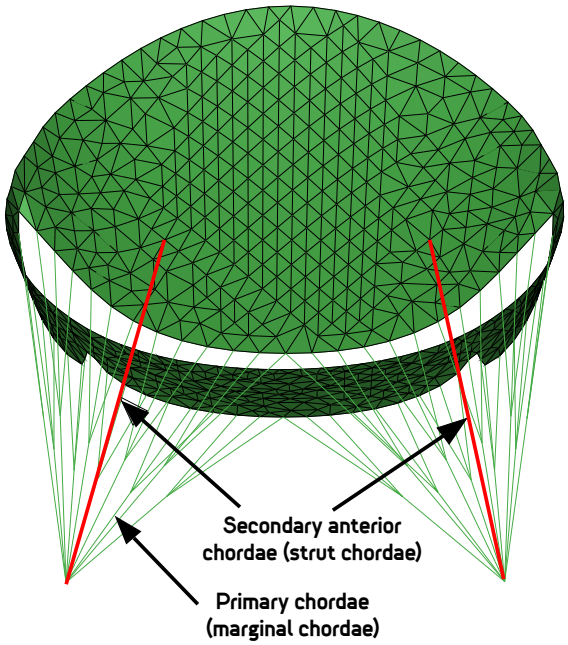
The Computational Geoscience project will be integrated in CBC in 2008 and therefore be described in next year's annual report.

## Featured Research 2007: Computational Modeling of the Mitral Valve

*Project leader: Bjørn Skallerud*

This section describes the current research done by the Biomechanics node at NTNU. The group consists of Leif Rune Hellevik and Bjørn Skallerud (professors), Paul Roger Leinan and Victorien Prot (PhD students), and Sigrid K. Dahl (research trainee).

Victorien Prot is about to finalize his PhD thesis on the topic "Modeling and Numerical Analysis of the Mitral Valve". He has derived constitutive models for the soft biological mitral tissue, which are suitable for implementation in nonlinear finite element codes. The finite element simulations have been validated through comparison with ultrasound recordings of pig mitral valves. Collaboration with heart surgeons, medical imaging experts, and cardiologists at St. Olav University Hospital has been very important for the outcome of the project. Also assistance from pathologists in investigating mitral valve anatomy has been very helpful. During this research, the relative load distribution in the chordae has been established, and the importance of the saddle shape of the annulus during physiological conditions has been investigated. Furthermore, we have illustrated the inaccuracies introduced by modeling the leaflets as a passive elastic material, not including effects of muscle fiber contraction. During the course of work, collaboration with Prof. G. A. Holzapfel, TU Graz has been established. Novel data on the mechanical response of both physiological and pathological human mitral tissue has resulted from this collaboration. This research has the potential of helping cardiac surgeons in improving mitral valve repair procedures and in providing a better understanding of the mitral valve function, ultimately improving patient diagnostics and treatment.




*Finite element model of mitral valve*

Two former master students, Paul Roger Leinan and Sigrid K Dahl at NTNU, were recruited in August/September 2007.

Sigrid Dahl will address fluid structure interaction (FSI) simulation of mitral valve dynamics in her future PhD research. The work will be a continuation of Dahl's master thesis, where ultrasound recordings were used to impose heart wall movement, while the mitral valve dynamics was simulated. The intention is to incorporate the novel models of Victorien Prot for the mitral leaflets in the FSI-simulations, and to use ultrasound recordings for imposition of structural movements and validation.
Paul Roger Leinan will also work with FSI simulation in his thesis, albeit with another application, namely wave propagation phenomena in human fetal venous blood vessels. Our long time collaborating partner Prof. Torvid Kiserud, University of Bergen and Haukeland University Hospital, will be the clinical expert and advisor in this project.

Leif Rune Hellevik studies 1D-models of wave propagation phenomena in blood vessel networks. Such models provide information

on pressure and flow waves which may be significant in predictive medicine (i.e., assessment of vascular disorders). However, equally important for CBC is that such 1D-network models may be used to provide flexible patient specific boundary conditions for 3D-FSI simulations. Collaborators in this project will be Prof. Geir K. Pedersen from the University of Oslo and the group of Prof. Didier Clamond from the University of Nice.

Bjørn Skallerud's research focuses on modeling of soft biological tissue and FSI analysis of the heart in general, and FSI in left ventricle/mitral valve region in particular.

## International Collaboration

The CBC had significant collaboration with researchers from eight different countries. The most substantial collaboration was with research groups in the US, but we also have close connections with universities in China and several European countries. We here give a brief description of the collaborations, sorted by country.

### Canada

We work on the Mathematics of Information Technology and Complex Systems (MITACS) project Efficient Numerical Time-Integration Methods for Unsteady Fluid Flow together with Prof. Raymond Spiteri at the University of Saskatchewan. Our industrial partners in this research include Martec, Ltd. of Halifax, NS, and IBM. MITACS is a Network of Centres of Excellence (NCE) for the Mathematical Sciences. Spiteri is Director of the Centre for High-Performance Computing at the University of Saskatchewan. As part of our ongoing collaboration with Spiteri, his master student Ryan Dean stayed 3 months at CBC to work on ODE solvers in collaboration with Joakim Sundnes.

### China

Xing Cai had a one-week visit to Hohai University of China in May 2007. The visit was part of a research collaboration initialization effort funded by a grant of the BILAT program of the Research Council of Norway. As the second part of this initial collaboration, Prof. Wen Chen from Hohai University paid a two-week visit to CBC in September/October 2007, together with three key members of his research group.

### France

Alf Emil Løvgren have visited and collaborated with Prof. Yvon Maday (four-week visit) and Nicole Poussineau (one-week visit), from Laboratoire Jacques-Louis Lions, Université Pierre et Marie Curie.

### Germany

Bjørn Fredrik Nielsen visited the University of Münster. Xing Cai had a two-week visit to the high-performance computing center (HLRS) at the University of Stuttgart in March 2007. The visit was supported by a grant of the HPC Europa Program.

### Spain

Prof. Stuart Hardy from Institució Catalana de Recerca i Estudis Avançats, Barcelona, paid a short visit to Xing Cai at CBC in November 2007. The focus of collaboration was an initial study on the subject of parallelizing Prof. Hardy's discrete element based numerical methods for modeling geological structures. Several parallelization approaches were tested and a draft of future collaboration tasks was written.

### Sweden

We have a long standing relationship with our neighbour country, and have recruited several Swedish researchers to the CBC project (Robert Artebrant, Anders Logg, Mats Larson, Malin Ljungberg, Malin Siklosi, and from 2008, Bjørn Anders Pettersson Reif).

Together with Prof. Michael Thuné and Prof. Sverker Holmgren from Uppsala University we hosted a workshop in Uppsala in August 2007, addressing challenging research issues in high-performance computing software.

### Switzerland

Alf Emil Løvgren was invited by Dr. Simone Deparis to École Polytechnique Fédérale De Lausanne to work with reduced basis functions. Dr. Deparis has also visited CBC to do research and present his work on one of our workshops.

### USA

Researchers at CBC have frequently partnered with colleagues in USA for joint research projects. During 2007, we have particularly strengthened our ties with University of California at San Diego (UCSD). Several of CBC's senior scientists spent time at UCSD during the year.

Prof. Andrew McCulloch, Dept. of Bioengineering at UCSD, is part of our Scientific Advisory Board, as well as Principal Investigator for the Biomedical Flows project.

The collaboration with Prof. Scott Baden, Dept. of Computer Science at UCSD, was formally started in 2007. The purpose is to enhance our competence and utilization of high-performance and parallel computing. The initial activities are described in the section on the Computational Middleware project.

In addition to our close links with UCSD, Xing Cai has a long-term collaboration with Prof. Jim Yeh from The University of Arizona. In 2007, this collaboration included co-editing a book titled Quantitative Information Fusion for Hydrological Sciences, which was published by Springer in January 2008. Dr. Geoff Bohling from Kansas Geological Survey, Kansas University, also paid a one-week visit to Xing Cai at CBC in October 2007. A preliminary study was done on the subject of parallelizing Dr. Bohling's hydraulic tomography software. Several parallelization approaches were tested and both sides agreed to continue this work in the future.

Researchers at CBC have ongoing research work with Prof. Robert C. Kirby at Texas Tech University and Dr. Matthew Knepley at Argonne National Laboratory, mostly on issues related to the Computational Middleware project. We have also recently initiated a collaboration with Prof. Victor Haughton, University of Wisconsin, on cerebrospinal fluid flow.

# Education and Outreach

Many people at CBC regularly teach courses at all levels at the University of Oslo. All of the courses are created by CBC researchers, and in many cases we have written associated textbooks, published by Springer.

In 2007 we spent considerable efforts on developing and teaching a new annual introductory programming course aimed at students in mathematically-oriented sciences. Our motivation for this effort was four-fold. First, we think the working style in computational science and engineering, where physics, mathematics, numerics, programming, and visualization are brought together to solve a problem, should be taught from the very beginning. At most universities, the students meet this working style at master or PhD level. Second, the introductory programming course at the University of Oslo (and most other places) teaches Java and aims at students with no mathematics background. For the students who take classical and numerical calculus the first semester, the programming course should teach them how to solve mathematical problems with aid of the computer. Third, a programming course using mathematical examples naturally brings in real-world applications of the mathematics to solve problems in physics, finance, and biology, for instance. Fourth, and perhaps most important, through this course we meet a lot of talented, promising young students, with a strong interest in mathematical subjects, who we can motivate to choose computational science and engineering as their specialization. We therefore look at the efforts with a new course as an excellent opportunity for a long-term investment in recruiting future candidates to our exciting research fields. Over 170 students managed to pass the final exam.

The new introductory programming course applies the Python language and teaches programming concepts through examples from the sciences where mathematics and numerical methods are key tools to solve problems. In other words, we give an introduction to computational science (and the working style of CBC) already in the first semester, and this is novel also in an international setting. It was therefore necessary to develop all the course material, including a textbook, a set of slides, and a large set of exercises and student projects. The student evaluation showed that even the first version of the course, given the fall of 2007, was a great success. We met a number of very talented and interested students, convincing us that this investment will pay off. For example, we made contact with highly potential candidates for summer internships at CBC. Later courses, including the first physics course, take advantage of the new students' ability to solve differential equations numerically and such courses can therefore attack more real-life problems than what is possible when solely using pen and paper. This modernization is part of a large project at the University of Oslo, called Computers in Science Education.

Aside from the educational efforts described so far, we did not put a high focus on disseminating our research results to a broad audience. However, some efforts were made in this direction and listed in the appendix. In particular, as mentioned in the description of the Inverse Problems project, an article in "Zürich Intelligencer" was distributed to over 3000 participants at the leading conference in applied and industrial mathematics.

# Appendix

**In the appendices below, we use several abbreviations:**

**ADM** = The Administration unit at Simula
**BF** = Biomedical Flows (CBC project)
**CC** = Cardiac Computing (CBC project)
**CM** = Computational Middleware (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
**UiO** = University of Oslo

## STAFF

**SENIOR SCIENTISTS 2007: 19 PEOPLE: 7,1 MAN-YEARS**

| Name | Gender | Position | Nationality | Period | CBC share | Funding | Project |
|---|---|---|---|---|---|---|---|
| Scott Baden | M | Professor | American | 11.06.07-10.06.09 | 20 % | CBC | CM |
| Xing Cai | M | Professor | Norwegian | 01.04.07-31.03.17 | 100 % | HOST | CC/CM |
| Per Grøttum | M | Professor | Norwegian | 01.08.07-31.12.08 | 20 % | CBC | IP |
| Leif Rune Hellevik | M | Professor | Norwegian | 24.05.07-31.03.17 | 50 % | NTNU | BF |
| Kenneth Hvistendahl Karlsen | M | Professor | Norwegian | 01.04.07-31.12.08 | 20 % | CBC | BF/CC |
| Hans Petter Langtangen | M | Professor | Norwegian | 01.04.07-31.03.17 | 100 % | HOST | CM |
| Mats G. Larson | M | Professor | Swedish | 01.04.07-31.05.08 | 40 % | 20% Umeå, 5% SSRI, 15% CBC | RFS |
| Glenn Terje Lines, | M | Research Scientist | Norwegian | 01.08.07-31.03.17 | 100 % | HOST | CC |
| Svein Linge | M | Research Scientist | Norwegian | 01.04.07-01.07.08 | 100 % | HOST | CC |
| Anders Logg | M | Research Scientist | Swedish | 01.04.07-31.07.09 | 100 % | CBC | RFS/CM |
| Kent-André Mardal | M | Research Scientist | Norwegian | 01.04.07-31.12.08 | 100 % | RCN grant 170650 | BF/CM/IP/RFS |
| Andrew D. McCulloch | M | Professor | New Zealand | 01.04.07-30.09.08 | 10 % | RCN YFF-grant 162730 | BF/CC |
| Bjørn Fredrik Nielsen | M | Research Scientist | Norwegian | 01.08.07-31.03.17 | 100 % | HOST | IP |
| Harald Osnes | M | Assoc. Professor | Norwegian | 01.08.07-31.12.08 | 20 % | CBC | CC |
| Bjørn Anders Petterson Reif | M | Professor | Swedish | 15.09.07-31.12.07 | 28 % | CBC | RFS |
| Bjørn Runar Skallerud | M | Professor | Norwegian | 24.05.07-31.03.17 | 20 % | NTNU | BF |
| Ola Skavhaug | M | Research Scientist | Norwegian | 01.04.07-31.12.08 | 100 % | HOST | CM/CC |
| Joakim Sundnes | M | Research Scientist | Norwegian | 01.04.07-31.03.17 | 50 % | 21% CBC 29% HOST | CC |
| Aslak Tveito | M | Professor | Norwegian | 01.08.07-31.03.17 | 25 % | HOST | CC |

**POST DOCS 2007: 8 PEOPLE: 4,1 MAN-YEARS**

| Name | Gender | Nationality | Period | CBC share | Funding | Project |
|---|---|---|---|---|---|---|
| Robert Artebrant | M | Swedish | 01.10.07-30.09.09 | 100 % | SSRI | CC |
| Monica Hanslien | F | Norwegian | 01.08.07-31.01.09 | 100 % | RCN grant 171164 | CC |
| Malin Ljungberg | F | Swedish | 01.05.07-30.04.08 | 100 % | CBC | CM |
| Alf Emil Løvgren | M | Norwegian | 01.04.07-31.12.09 | 100 % | 90% NTNU, 10% CBC | RFS |
| Mary MacLachlan | F | Canadian | 01.04.07-31.10.08 | 100 % | RCN YFF-grant 162730 | CC |
| Pearu Peterson | M | Estonian | 07.05.07-30.04.08 | 100 % | CBC | CM |
| Shubeur Rahman | M | British | 27.08.07-26.10.07<br>19.11.07-16.12.07 | 100 % | CBC | BF |
| Malin Siklosi* | F | Swedish | 01.05.07-31.10.07 | 75 % | CBC | BF |

** Malin Siklosi has had a leave of absence during the periods: 15.06.07 - 06.08.07 and 16.08.07 - 31.10.07*

**PHD STUDENTS 2007: 7 PEOPLE: 3,2 MAN-YEARS**

| Name | Gender | Nationality | Period | CBC share | Funding | Project |
|---|---|---|---|---|---|---|
| Martin Sandve Alnæs | M | Norwegian | 01.08.07-31.07.09 | 100 % | RCN YFF-grant 162730 | CC/ CM |
| Rolv Erlend Bredesen | M | Norwegian | 01.04.07-10.06.09 | 100 % | 90% UiO + 10% CBC | CM |
| Johan Elon Hake | M | Swedish | 01.08.07-30.06.08 | 100 % | HOST | CC |
| Paul Roger Leinan | M | Norwegian | 10.09.07-10.09.11 | 100 % | NTNU | BF |
| Victorien Prot | M | French | 24.05.07-31.12.07 | 100 % | NTNU | BF |
| Tomas Syrstad Ruud | M | Norwegian | 01.08.07-31.07.08 | 100 % | HOST | IP |
| Didem Unat | F | Turkish | 11.09.07-10.09.11 | 100 % | CBC | CM |

**TECHNICAL AND ADMINISTRATIVE STAFF 2007: 10 PEOPLE: 3,5 MAN-YEARS**

| Name | Position | Gender | Nationality | Period | CBC share | Funding | Project |
|---|---|---|---|---|---|---|---|
| Wenche Angel | Executive Officer Economy | F | Norwegian | 01.04.07-31.03.17 | 10 % | HOST | ADM |
| Tom David Atkinson | Administrative Manager | M | Norwegian | 01.05.07-31.03.17 | 100 % | CBC | ADM |
| Sigrid Kaarstad Dahl | Research Trainee | F | Norwegian | 15.08.07-14.08.08 | 100 % | CBC | BF |
| Anders Helgeland | Research Scientist | M | Norwegian | 01.06.07-31.12.09 | 20 % | CBC | BF |
| Hege Johnsrud | Financial Officer | F | Norwegian | 01.04.07-31.03.18 | 5 % | HOST | ADM |
| Oddrun Myklebust | Research Trainee | F | Norwegian | 15.08.07-14.08.08 | 100 % | SSRI | BF |
| Johannes Hofaker Ring | Scientific programmer | M | Norwegian | 01.06.07-31.12.08 | 100 % | 73% UiO 27% CBC | CM |
| Kristian Valen- Sendstad | Research Trainee | M | Norwegian | 21.05.07-20.05.08 | 100 % | SSRI | BF |
| Åsmund Ødegård | Scientific programmer | M | Norwegian | 01.04.07-31.12.07 | 50 % | HOST | CM |
| Wenjie Wei | Research Trainee | M | Chinese | 01.10.07-30.09.08 | 100 % | SSRI | CC |

## 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.

We have nearly doubled our budget during the start-up year with an increase from 9.000.000,- to 17.000.000,- NOK. By expanding the scope of CBC, we managed to almost double the contribution from our host institution. In addition to this we established partnerships with The Norwegian University of Science and Technology, Simula School of Research and Innovation, University of Oslo, and Umeå University that contributed with an income in kind of 3.277.000,- NOK to the center.

By this major new increase of funding, the SFF grant from the Research Council of Norway now represents only 1/3 of the total funding of CBC, instead of the approximately 2/3 that was originally intended in our proposal. Due to our rapid increase of the budget, we have an

end of year surplus of 1.478.000,- NOK for 2007, and we have revised our budget for 2008 in accordance to our new financial situation.

One of the hopes for the Norwegian Centers of Excellence is that the excellence status and long-term funding should help them to attract the interest of other scientists and obtain additional research funding. It is fair to claim that CBC has been very successful in this respect already in the start-up year. We definitely need to consolidate the scientific activities arising from the present budget increase before it makes sense to take new initiatives regarding financial expansions.

| OPERATING REVENUES: | Note | Budget 2007 | Account 2007 | Budget 2008 |
|---|---|---|---|---|
| RCN CoE founding | | 5,664 | 5,664 | 7,500 |
| Allocation from earlier years | | | 0 | 1,478 |
| Host - Simula Research Laboratory (SRL) | | 3,361 | 6,541 | 9,577 |
| Other income RCN | 1 | | 1,556 | 3,993 |
| Other income | 2 | | 48 | |
| **Sum operating revenues** | | **9,025** | **13,809** | **22,548** |
| | | | | |
| **Income in kind:** | | | | |
| Simula School of Research and Innovation AS (SSRI) | 3 | | 1,103 | 2,676 |
| Norwegian University of Science and Technology (NTNU) | 4 | | 1,425 | 1,168 |
| University of Oslo (UiO) | 5 | | 641 | |
| University of Umeå | 6 | | 108 | |
| **Sum income in kind** | | **0** | **3,277** | **3,844** |
| **Total income** | | **9,025** | **17,086** | **26,392** |
| | | | | |
| OPERATING EXPENSES: | | | | |
| Cost of labour | | 5,634 | 8,388 | 16,786 |
| Indirect costs | 7 | 1,408 | 1,996 | 3,013 |
| Outsourcing of R & D services | 8 | 400 | 83 | 891 |
| Other operating expenses | 9 | 1,583 | 1,864 | 2,153 |
| **Sum operating expenses** | | **9,025** | **12,331** | **22,843** |
| | | | | |
| **Operating expenses in kind:** | | | | |
| Cost of labour | | | 2,474 | 2,691 |
| Indirect costs | 7 | | 359 | 673 |
| Other operating expenses | 9 | | 444 | 480 |
| **Sum operating expenses in kind** | | **0** | **3,277** | **3,844** |
| **Total operating expenses** | | **9,025** | **15,608** | **26,687** |
| **Year end allocation** | | **0** | **1,478** | **-295** |

***Note 1:*** *RCN grant 162730: YFF - Computing the Mechanics of the Heart: 583*
*RCN grant 171164: Numerical Simulations of Cardiac Arrhythmia and Defibrillation: 301*
*RCN grant 170650: Mixed Methods for the Stress-Displacement Formulation of Elasticity: 542*
*RCN grant 180423: China - Numerical Methods and Software for Modeling Seepage in Porous Media: 130*

***Note 2:*** *NTNU hiring office for Postdoc A. E. Løvgren: 38*
*Telenor iLabs grant: 10*

***Note 3:*** *Simula Research Laboratory's subsidiary Simula School of Research and Innovation AS is responsible for all educational activities in Simula Research Laboratory. The Simula School has financed the work of postdoc R. Artebrant and three research trainees: W. Wei, K. Valen-Sendstad and O. Myklebust*

***Note 4:*** *Contributions from the Norwegian University of Science and Technology: One postdoc position: A. E. Løvgren; two PhD students: V. Prot and P. R. Leinan and two professors: L. R. Hellevik and B. R. Skallerud in part time positions*

***Note 5:*** *Contributions from the University of Oslo: Part of labour cost for PhD student: R. E. Bredesen and scientific programmer: J. H. Ring*

***Note 6:*** *Contributions from the Umeå University: Part time funding of Prof. M. Larson*

***Note 7:*** *Indirect costs covers the cost of offices and infrastructure to all employees*

***Note 8:*** *The outsourced R&D project at SINTEF was postphoned, hence the increase of the R&D budget for 2008*

***Note 9:*** *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.

Since we started working with the proposal for CBC in 2005, we directed our research toward the center's goal. It is therefore natural to list the results of research work done before the official start of CBC. Also, most annual reports of the Centers of Excellence started in 2003 report all papers published in the start-up year, and we have thus followed the same custom (that is, we list all relevant publications that were printed in 2007).

## Articles in International Journals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2) R.E. Bensow, **M. G. Larson**, and P. Vesterlund. Vorticity-strain residual based turbulence modeling of the Taylor-Green vortex. *International Journal for Numerical Methods in Fluids*, **54**, no. 6-8, 745-756, 2007.

3) **X. Cai** and N. Bouhmala. A unified framework of multi-objective cost functions for partitioning unstructured finite element meshes. *Applied Mathematical Modelling*, **31**, no. 9, 1711-1728, 2007.

4) **X. Cai, B. F. Nielsen,** and **A. Tveito**. A note on the efficiency of the Conjugate Gradient method for a class of time-dependent problems. *Numerical Linear Algebra with Applications*, **14**, no. 5, 459-467, 2007.

5) S. Glimsdal, G. K. Pedersen, **H. P. Langtangen**, V. Shuvalov, and H. Dypvik. Tsunami generation and propagation from the Mjølnir asteroid impact. *Meteoritics & Planetary Science*, **42**, no. 9, 1473-1493, 2007.

6) **M. Hanslien, J. Sundnes,** and **A. Tveito**. An unconditionally stable numerical method for the Luo-Rudy 1 model used in simulations of defibrillation. *Mathematical Biosciences*, **208**, no. 2, 375-392, 2007.

7) K. Holmås and **H. P. Langtangen**. A sharp interface finite element method for elliptic interface problems; formulation and investigation in one space dimension. *International Journal of Pure and Applied Mathematics*, **34**, no. 3, 287-312, 2007.

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10) **A. Logg** and R. C. Kirby. Efficient compilation of a class of variational forms. *ACM Transactions on Mathematical Software*, **33**, no. 3, 2007.

11) **M. C. MacLachlan, J. Sundnes,** and R. J. Spiteri. A comparison of non-standard solvers for ODEs describing cellular reactions in the heart. *Computer Methods in Biomechanics and Biomedical Engineering*, **10**, no. 5, 317-326, 2007.

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13) **K.-A. Mardal, B. F. Nielsen, X. Cai,** and **A. Tveito**. An order optimal solver for the discretized Bidomain equations. *Numerical Linear Algebra with Applications*, **14**, no. 2, 83-98, 2007.

14) **K.-A. Mardal**, T. K. Nilssen, and G. A. Staff. Order optimal preconditioners for implicit Runge-Kutta schemes applied to parabolic PDE's. *SIAM Journal of Scientific Computing*, **29**, no. 1, 361-375, 2007.

15) **K.-A. Mardal, O. Skavhaug, G. T. Lines**, G. A. Staff, and **Å. Ødegård**. Using python to solve partial differential equations. *Computing in Science & Engineering*, **9**, no. 3, 48-51, 2007.

16) **B. F. Nielsen, X. Cai,** and O. M. Lysaker. On the possibility for computing the transmembrane potential in the heart with a one shot method; an inverse problem. *Mathematical Biosciences*, **210**, no. 2, 523-553, 2007.

17) **B. F. Nielsen**, O. M. Lysaker, and **A. Tveito**. On the use of the resting potential and level set methods for identifying ischemic heart disease; an inverse problem. *Journal of Computational Physics*, **220**, no. 2, 772-790, 2007.

18) **B. F. Nielsen, T. S. Ruud, G. T. Lines,** and **A. Tveito**. Optimal Monodomain approximations of the Bidomain equations. *Applied Mathematics and Computation*, **184**, no. 2, 276-290, 2007.

19) **V. Prot, B. Skallerud,** and G. Holzapfel. Transversely isotropic membrane shells with application to mitral valve mechanics. *International Journal for Numerical Methods in Engineering*, **71**, no. 8, 987-1008, 2007.

20) **S. Rahman, H. P. Langtangen,** and C. H. W. Barnes. A finite element method for modeling electromechanical wave propagation in anisotropic piezoelectric media. *Communications in Computational Physics*, **2**, no. 2, 271-292, 2007.

21) **S. Rahman**, T. M. Stace, **H. P. Langtangen**, M. Kataoka, and C. H. W. Barnes. Pulse-induced acoustoelectric vibrations in surface-gated GaAs-based quantum devices. *Physical Review B*, **75**, (205303), 2007.

22) A. Schroll, **G. T. Lines,** and **A. Tveito**. On the accuracy of operator splitting as applied to discretized reaction diffusion systems. *International Journal of Computer Mathematics*, **84**, no. 6, 871 - 885, 2007.

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1) O. Al-Khayat, A. M. Bruaset, and **H. P. Langtangen**. Lattice Boltzmann method and turbidity flow modeling. In *Fourth National Conference on Computational Mechanics* (MekIT'07), edited by B. Skallerud and H. I. Andersson. 213–228. Tapir Academic Press, 2007.

2) **M. S. Alnæs**, **K.-A. Mardal,** and **J. Sundnes**. Application of symbolic finite element tools to nonlinear hyperelasticity. In *Fourth National Conference on Computational Mechanics* (MekIT'07), edited by B. Skallerud and H. I. Andersson. 87-101. Tapir Academic Press, 2007.

3) **R. E. Bredesen**, **H. P. Langtangen,** and G. Pedersen. Benchmark of a tsunami run-up code. In *Fourth National Conference on Computational Mechanics* (MekIT'07), edited by B. Skallerud and H. I. Andersson. 127-134. Tapir Academic Press, 2007.

4) **X. Cai** and **H. P. Langtangen**. Making hybrid tsunami simulators in a parallel software framework. In *Proceedings of the PARA'06 Workshop*, edited by B. Kågström, E. Elmroth, J. Dongarra, J. Wasniewski. 686-693. Lecture Notes in Computer Science, volume 4699, Springer, 2007.

5) J. B. Haga, A. M. Bruaset, **X. Cai, H. P. Langtangen, H. Osnes,** and J. Skogseid. Parallelisation and numerical performance of a 3D model for coupled deformation, fluid flow and heat transfer in sedimentary basins. In *Fourth National Conference on Computational Mechanics* (MekIT'07), edited by B. Skallerud and H. I. Andersson. 151-162. Tapir Academic Press, 2007.

6) **L. R. Hellevik, S. K. Dahl,** and **B. Skallerud**. A first-approach towards patient-specific 2D FSI-simulation of mitral valve dynamics during diastolic filling. In *Fourth National Conference on Computational Mechanics* (MekIT'07), edited by B. Skallerud and H. I. Andersson. 175-184. Tapir Academic Press, 2007.

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8) **A. Logg.** Efficient representation of computational meshes. In *Fourth National Conference on Computational Mechanics* (MekIT'07), edited by B. Skallerud and H. I. Andersson. Tapir Academic Press, 2007.

## Chapters in Books

1) **A. Logg, K.-A. Mardal, M. S. Alnæs, H. P. Langtangen,** and **O. Skavhaug**. A hybrid approach to efficient finite element code development. In *Petascale Computing - Algorithms and Applications*, edited by D. A. Bader. Computational Science. Chapman and Hall, 2007.

2) **A. E. Løvgren**, E. M. Rønquist, and Y. Maday. The reduced basis element method for fluid flows. In *Analysis and Simulation of Fluid Dynamics*, edited by C. Calgaro, J.-F. Coulombel, and T. Goudon. 129–154. Advances in Mathematical Fluid Mechanics. Birkhäuser, 2007.

## Technical Reports

1) **H. Osnes**. Mohr-Coulomb Stress in the Code for Deformation and Heat Flow in Sedimentary Basins. *Simula Research Laboratory, Project report*, 2007.

## Manuals

1) **M. S. Alnæs, A. Logg, K.-A. Mardal, O. Skavhaug,** and **H. P. Langtangen**. UFC Specification and User Manual 1.0. *Manual*, 2007.

2) **A. Logg.** FFC User Manual. *Manual*, 2007.

3) **A. Logg**, J. Hoffman, J. Jansson, and G. N. Wells. DOLFIN User Manual. *Manual*, 2007.

## Talks

1) O. Al-Khayat, A. M. Bruaset and **H. P. Langtangen**. Lattice Boltzmann method and turbidity flow modeling. Talk at *Fourth national conference on Computational Mechanics* (MekIT'07), Trondheim, May 23-24, 2007.

2) **M. S. Alnæs.** Computing the mechanics of the heart. Talk at *CBC Seminar on Electrophysiology Modeling*, Simula, September 6, 2007.

3) **M. S. Alnæs**, **K.-A. Mardal,** and **J. Sundnes**. Application of symbolic finite element tools to nonlinear hyperelasticity. Talk at *Fourth national conference on Computational Mechanics* (MekIT'07), Trondheim, May 23-24, 2007.

4) **S. Baden.** Overcoming obstacles with graph based programming models. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

5) **S. Baden.** A data centric view of scientific computing. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

6) **S. Baden.** A sustainable software ecosystem. Talk at *CBC Workshop on High-Performance and Parallel Computing*, Simula, October 24, 2007.

7) **R. E. Bredesen**, **H. P. Langtangen,** and G. Pedersen. Benchmark of a tsunami run-up code. Talk at *Fourth national conference on Computational Mechanics* (MekIT'07), Trondheim, May 23-24, 2007.

8) **X. Cai.** Building hybrid parallel PDE software by domain decomposition and object-oriented programming. Talk at the *ICCM 2007 Conference*, April 4-6, Hiroshima, Japan, 2007.

9) **X. Cai**. Making parallel PDE software by object-oriented programming. Guest lecture given at *Hohai University*, China, May 17, 2007.

10) **X. Cai**. On building parallel algorithms and software for hydraulic tomography. Talk at *SIAM GS2007 Conference*, Santa Fe, New Mexico, USA, March 19-22, 2007.

11) **X. Cai**. Simulating tsunami propagation on parallel computers using a hybrid software framework. Guest lecture given at the *University of Stuttgart*, March 12, 2007.

12) **X. Cai** and **H. P. Langtangen**. On a future software platform for demanding multi-scale and multiphysics problems. Talk at *SIAM CSE07 Conference*, Costa Mesa, CA, February 19-23, 2007.

13) **S. K. Dahl**. A first-approach towards patient-specific 2D FSI-simulation of mitral valve dynamics during diastolic filling. Talk at *Fourth national conference on Computational Mechanics* (MekIT'07), Trondheim, May 23-24, 2007.

14) **S. K. Dahl**. A first-approach towards patient-specific 2D FSI-simulation of mitral valve dynamics during diastolic filling. Talk at *CBC Seminar on Biomechanics*, Trondheim, November 15, 2007.

15) H. Enger, J. Feder, A. Malthe-Sørenssen, and **H. P. Langtangen**. Optimal coupling in a multiscale model. Poster at the *Kongsberg Seminar on geology*, Kongsberg, 2007.

16) **J. E. Hake.** Subcellular calcium handling. Talk at *CBC Seminar on Electrophysiology Modeling*, Simula, September 6, 2007.

17) **J. E. Hake** and **G. T. Lines**. Stochastic binding of Ca2+ ions in the dyadic cleft continuous vs Random walk description of diffusion. Poster presentation at *5th Annual CHFR Symposium*, Oslo, October 10-11, 2007.

18) **J. E. Hake** and **G. T. Lines**. Stochastic binding of Ca2+ ions in the dyadic cleft continuous vs Random walk description of diffusion. Talk at the *6th International Congress on Industrial and Applied Mathematics (ICIAM 07)*, Zürich, July 18, 2007.

19) J. B. Haga, A. M. Bruaset, **X. Cai, H. P. Langtangen, H. Osnes,** and J. Skogseid. Parallelisation and numerical performance of a 3D model for coupled deformation, fluid flow and heat transfer in sedimentary basins. Talk at *Fourth National Conference on Computational Mechanics* (MekIT'07), Trondheim, May 23-24, 2007.

20) **M. Hanslien.** Stable numerical methods for cell models used in simulations of ventricular defibrillation. Talk at *CBC Seminar on Electrophysiology Modeling*, Simula, September 6, 2007.

21) H. Holmås, D. Clamond, and **H. P. Langtangen**. A pseudospectral Fourier method applied to an incompressible two-fluid model. Talk at the *International Conference on Multiphase Flow* (ICMF 2007), Leipzig, 2007.

22) **H. P. Langtangen**. Computational modeling of huge tsunamis from asteroid impacts. Invited keynote lecture at *the International conference on Computational Science 2007* (ICCS'07), Beijing, China, 2007.

23) **M. G. Larson.** Multiscale modeling of turbulent flow. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

24) **M. G. Larson.** Adaptivity and error estimation for multiphysics problems. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

25) **P. R. Leinan.** Simulations and experiments with the BSCC mechanical heart valve prosthesis. Talk at *CBC Seminar on Biomechanics*, Trondheim, November 15, 2007.

26) **G. T. Lines.** Cardiac computing at Simula. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

27) **G. T. Lines.** Overview of the Cardiac Computations project. Talk at *CBC Seminar on Electrophysiology Modeling*, Simula, September 6, 2007.

28) **M. Ljungberg.** Requirements on PDE solver components for multiphysics simulations. Talk at *Workshop on Software Issues in Computational Science and Engineering*, Uppsala, August 15-16, 2007.

29) **A. Logg**. Activities at Simula: FEniCS and the Center for Biomedical Computing. *Computational and Applied Mathematics Seminar*, Chalmers Göteborg, September 26, 2007.

30) **A. Logg**. Automated solution of differential equations. Talk at the *6th International Congress on Industrial and Applied Mathematics* (ICIAM 2007), Zürich, July 18, 2007.

31) **A. Logg.** Efficient representation of computational meshes. Talk at *Fourth national conference on Computational Mechanics* (MekIT'07), Trondheim, May 23-24, 2007.

32) **A. Logg.** Finite element code generation: Simplicity, generality, efficiency. Talk at *Workshop on Software Issues in Computational Science and Engineering*, Uppsala, August 15-16, 2007.

33) **A. Logg.** Finite element code generation: Simplicity, generality, efficiency. Talk at *Software Issues in Computational Science and Engineering* (SCSE 2007), Uppsala, August 11, 2007.

34) **A. Logg** and **O. Skavhaug.** Software tools for partial differential equations. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

35) O. M. Lysaker and **B. F. Nielsen**. PDE methods for identifying ischemic heart disease. Presented at the *6th International Congress on Industrial and Applied Mathematics* (ICIAM 2007), Zürich, July 18, 2007.

36) **A. E. Løvgren.** Reduced Basis Modeling of Complex Flow Systems. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

37) **M. MacLachlan.** Simulation of atrial arrhythmias. Talk at *CBC Seminar on Electrophysiology Modeling*, Simula, September 6, 2007.

38) **K.-A. Mardal.** Computation of hemodynamics in the Circle of Willis. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

39) **K.-A. Mardal** and **M. S. Alnæs.** Finite elements with symbolic computations and code generation. Talk at *Workshop on Software Issues in Computational Science and Engineering*, Uppsala, August 15-16, 2007.

40) **A. McCulloch.** Multi-scale modeling of cardiac electromechanical interactions. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

41) **B. F. Nielsen.** Inverse solutions for assessing myocardial ischemia. Talk at *CBC Seminar on Electrophysiology Modeling*, Simula, September 6, 2007.

42) **P. Peterson.** The G3 F2PY for connecting Python and Fortran 90 programs. Talk at *Workshop on Software Issues in Computational Science and Engineering*, Uppsala, August 15-16, 2007.

43) **V. Prot.** Solid finite element analysis of the mitral valve. Talk at *CBC Seminar on Biomechanics*, Trondheim, November 15, 2007.

44) **V. Prot, B. Skallerud,** and G. Holzapfel. Effects on connective tissue pathologies on mitral valve response. Talk at the *Conference on Modelling of heterogeneous materials with application in construction and biomedical engineering*, Prague, June 25-27, 2007.

45) **B. Skallerud.** Modeling of the mitral valve in the heart. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

46) **M. Siklosi.** Multiscale modeling of the acoustic properties of lung parenchyma. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

47) **J. Sundnes**. Computational techniques for heart muscle mechanics. Minisymposium talk at the *6th International Congress on Industrial and Applied Mathematics* (ICIAM 2007), Zürich, July 18, 2007.

48) **J. Sundnes**. Software components for biomedical flows. Talk at the *National Seminar on Medical Technology*, NFA (Norsk forening for automatisering), Oslo, September 18, 2007.

49) **J. Sundnes.** Using mathematical models to test physiological hypotheses. Invited talk at the annual meeting of the *Scandinavian Physiological Society*, August 10, 2007

50) **J. Sundnes, M. S. Alnæs,** and **K.-A. Mardal**. A finite element model of cardiac electrophysiology and mechanics. Talk at the *VII International Conference on Computational Plasticity*, September 5, 2007.

51) **Å. Ødegård.** Challenges with distributing the PyCC environment. Talk at *CBC Workshop on Biomedical Computing*, Simula, June 7-14, 2007.

# 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.

CBC has hosted five workshops and five seminars during 2007, with a total of 270 participants representing 17 different nationalities.

In order for us to explore the opportunity for new research ideas and to find new research partners, we have invited a large number of international speakers to our workshops. It has been a good experience, especially for our younger researchers, to present their own work to leading researchers in their field, and to be inspired by our guests' work. Hosting a week long workshop on biomedical processes in June, only a couple of months after our start-up, gave us a flying start and a good basis for choosing which direction we should concentrate our future efforts in this vast research field.

## Workshops

**June 7-14, 2007: Workshop on Biomedical Computing**
The purpose of this one-week workshop is to bring together collaborators of the center and international scientists working with topics of relevance for the center.

Total number of participants: 78
Number of different nationalities represented: 13
Total number of speakers: 37
Total number of talks: 37

The headlines for the various days were as follows:
**Thursday, June 7** - *Building, Installing and Distributing Scientific Software*
**Friday, June 8** - *Numerical Methods for Fluid Flow*
**Monday, June 11** - *Modeling and Simulation of Biomedical Processes*
**Tuesday, June 12** - *Modeling and Simulation of Biomedical Processes*
**Wednesday, June 13** - *Modeling and Simulation of Biomedical Processes*
**Thursday, June 14** - *Turbulence & Aerosol Modeling*

Invited international speakers include:
- Prof. Per Ask, Linköping University
- Prof. Scott Baden, University of California, San Diego
- Prof. William K. George,Chalmers University of Tech., Gothenburg
- Prof. Robert C. Kirby, Texas Tech University
- Dr. Matthew Knepley, Argonne National Laboratory
- Prof. Mats G. Larson, Umeå University
- Prof. Andrew McCulloch, University of California, San Diego
- Prof. Robert Schroter, Imperial College, London
- Dr. Sarah Waters, University of Nottingham
- Dr. Robert J. Whittaker, University of Nottingham

**August 15-16, 2007: Workshop on Software Issues in Computational Science and Engineering**
This workshop addressed challenging research issues regarding software for numerical computations. CBC organized the workshop in cooperation with Uppsala University and the Swedish National Infrastructure for Computing (SNIC).

Total number of participants: 43
Number of different nationalities represented: 12
Total number of speakers: 14
Total number of talks: 14

Invited international speakers include:
- Dominik Goeddeke, Universität Dortmund
- Prof. Bill Gropp, Argonne National Laboratory
- Dr. Richard Hanson, Visual Numerics, Inc.
- Prof. Sverker Holmgren, Uppsala University and Swedish National Infrastructure for Computing
- Dr. Fred Krogh, Visual Numerics, Inc.
- Prof. Bo Kågström, Umeå University
- PhD student Ioan Lucian Muntean, TU München
- Prof. Christoph Pflaum, University of Erlangen
- Dr. Tiago Quintino, von Karman Institute for Fluid Dynamics
- Prof. Gerhard Zumbusch, Friedrich-Schiller-Universität Jena

**September 6, 2007: Workshop on Electrophysiology Modeling**
A one-day workshop featured invited speaker Dr. Kirsten ten Tusscher and speakers from the Cardiac Computations project at CBC. Dr. ten Tusscher presented her model for human ventricular cells and also talked about recent work on ventricular arrhythmias.

Total number of participants: 13
Number of different nationalities represented: 4
Total number of speakers: 7
Total number of talks: 8

Invited international speaker:
- Dr. Kirsten H. W. J. ten Tusscher, Utrecht University

**October 24, 2007: Workshop on High-Performance and Parallel Computing**
This one-day workshop focused on new architectures and novel programming techniques for parallel computing. In particular, talks concerned multi-core and GPU architectures, and associated enabling software tools.

Total number of participants: 41
Number of different nationalities represented: 8
Total number of speakers: 8
Total number of talks: 8

Invited international speakers include:

- Prof. Scott Baden, University of California, San Diego
- Prof. Sverker Holmgren, Uppsala University and Swedish National Infrastructure for Computing
- Prof. Christoph Pflaum, University of Erlangen

**December 4-6, 2007: CBC Winter Workshop in Berlin**
The main focus of this workshop was to bring all collaborators in the CBC project together to inspire, share recent progress in the different projects, and to discuss new research challenges.

Total number of participants: 39
Number of different nationalities represented: 3
Total number of speakers: 19
Total number of talks: 27

Invited international speaker:

- Prof. Peter Deuflhard, ZIB, Berlin

## Seminars

**May 3, 2007:** CBC Opening seminar
**May 4, 2007:** Seminar on Requirements of PDE solver components for multiphysics simulations
**June 19-21, 2007:** CFD course (with Star-CD)
**October 1, 2007:** Intensive one-day seminar on Python programming
**November 15, 2007:** Seminar on biomechanics (at NTNU)

For more information about our conferences, workshops, seminars, and talks, please visit our website: www.simula.no/cbc.

# OTHER ACTIVITIES

## Media Appearances

There have been numerous media appearances regarding the start of CBC, establishing the partnership with NTNU and Anders Logg being awarded with an Outstanding Young Investigator (YFF) grant. We have, however, chosen to list only those appearances that focus directly on our research, or the outcome of research done at CBC.

The research done on the Circle of Willis in cooperation with the medical doctors Jørgen G. Isaksen and Tor Ingebrigtsen at the University hospital of Northern Norway got substantial media coverage and was picked up by several newspapers:

**Telemarksavisa, 03.09.2007:**
www.ta.no/Innenriks/helse/article2966568.ece
**Firda, 03.09.2007:**
www.firda.no/Innenriks/helse/article2966568.ece?service=print
**Avisa Nordland, 03.09.2007:**
www.an.no/Innenriks/helse/article2966568.ece
**Østlandsposten, 03.09.2007:**
www.op.no/Innenriks/helse/article2966568.ece
**Hardanger Folkeblad, 03.09.2007:**
www.hardanger-folkeblad.no/Innenriks/helse/article2966568.ece
**Aura Avis, 03.09.2007:**
www.auraavis.no/Innenriks/helse/article2966568.ece
**Aust Agder Blad, 03.09.2007:**
www.austagderblad.no/Innenriks/helse/article2966568.ece
**Ringerikes Blad, 03.09.2007:**
www.ringblad.no/Innenriks/helse/article2966568.ece
**Akershus Amtstidende, 03.09.2007:**
www.amta.no/Innenriks/helse/article2966568.ece
**Sarpsborg Arbeiderblad, 03.09.2007:**
www.sa.no/Innenriks/helse/article2966568.ece
**Finnmarken, 03.09.2007:**
www.finnmarken.no/Innenriks/helse/article2966568.ece
**Smaalenenes Avis, 03.09.2007:**
www.smaalenene.no/magasiner/helse/article2966568.ece

## Refereeing Activities

During 2007, employees at CBC have refereed manuscripts for:

- *A*Star*
- *ACM Transactions on Mathematical Software*
- *Advances in Water Resources*
- *American Association for the Advancement of Science*
- *American Journal of Physiology*
- *Annals of Biomedical Engineering*
- *ASME Journal of Fluids Engineering*
- *Biophysical Journal*
- *BIT Numerical Mathematics*
- *Cardiovascular Research*
- *Cell*
- *Circulation*
- *Circulation Research*
- *Computer Methods in Biomechanics and Biomedical Engineering*
- *Experimental Physiology*
- *Flow, Turbulence and Combustion*
- *Heart Rhythm*
- *IEEE transactions on biomedical engineering*
- *International Journal of Computational Science and Engineering*
  *Advances in Engineering Software*
- *Journal of Biomechanical Engineering*
- *Journal of Cardiovascular Electrophysiology*
- *Journal of Cellular and Molecular Cardiology*
- *Journal of the American College of Cardiology*
- *Journal of Scientific Computing*
- *Mathematical Biosciences*
- *Mathematical Reviews (AMS)*
- *Molecular Systems Biology*
- *Nature Biotechnology*
- *Nature Protocols*
- *New Zealand Foundation for Research Science and Technology*
- *New Zealand Health Research Council*
- *Nonlinear Analysis*

- *Ocean Engineering*
- *Physics of Fluids*
- *Physiological Measurement*
- *Proceedings of the National Academy of Sciences*
- *Progress in Biophysics and Molecular Biology*
- *Science*
- *SIAM Journal of Scientific Computing*
- *Springer Verlag*
- *The 4th IEEE Int. Symposium on Embedded Computing (SEC-07)*
- *The 7th International Conference on Parallel Processing and Applied Mathematics (PPAM'07)*
- *The Royal Society (London)*

## Awards/Public Recognition

- **A. Logg** was awarded an Outstanding Young Investigator (YFF) grant from the Research Council of Norway.
- **A. McCulloch** appeard on the ABC Radio The Science Show: Modelling the Heart, with Robyn Williams, on April 28th, 2007.
- **B. F. Nielsen** received the "2007 Simula Research Award".
- **B. A. P. Reif** was placed second for the Henry J. E. Reid Award at NASA Langley Research Center, Hampton VA. for the most outstanding scientific paper (covering all scientific activities at NASA Langley).

## Editorial Boards

Employees of the center are on the following editorial boards:

**K. H. Karlsen:**
- Journal of Hyperbolic Differential Equations
- Networks and Heterogeneous Media
- SIAM Journal on Numerical Analysis

**H. P. Langtangen:**
- Advances in Water Resources
- BIT Numerical Mathematics
- International Journal of Applied Mathematics & Computational Sciences
- International Journal of Computational Science and Engineering
- International Journal of Oceans and Oceanography
- Mathematical Modelling and Applied Computing
- SIAM Journal on Scientific Computing

**A. McCulloch:**
- ASME Journal of Biomechanical Engineering
- Cellular and Molecular Bioengineering
- Computer Methods in Biomechanics and Biomedical Engineering
- Drug Discovery Today: Disease Models *(Editor in Chief)*
- Synthetic and Systems Biology

**B. A. P. Reif:**
- International Journal of Heat and Fluid Flow.

**J. Sundnes:**
- Simulation modelling practice and theory.

**A. Tveito:**
- SIAM Journal on Scientific Computing
- Computing and Visualization in Science

## Conference Committees

- **X. Cai:** Member of Technical Committee of The 4th IEEE International Symposium on Embedded Computing (SEC-07)
- **H. P. Langtangen:** IFIP WG 2.5 Workshop on Software Issues in Computational Science and Engineering 2007
- **H. P. Langtangen:** Parallel Computing 2007 Conference (ParCo2007)
- **H. P. Langtangen:** The 4th National Conference on Computational Mechanics (Mek-IT'07).
- **A. McCulloch:** Track Chair, New Frontiers track, BMES annual meeting
- **A. McCulloch:** Program Committee, RECOMB Satellite Conferences on Systems Biology, 2007

## Organization of Minisymposiums at Conferences

- **K. H. Karlsen:** ICIAM (International Council for Industrial and Applied Mathematics) 2007, Zurich: - *Nonlocal conservation laws* (with Helge Holden)
- **K. H. Karlsen:** ICIAM (International Council for Industrial and Applied Mathematics) 2007, Zurich: - *Conservation laws with discontinuous flux* (with Raimund Bürger)
- **J. Sundnes:** ICIAM (International Council for Industrial and Applied Mathematics) 2007, Zurich:- *Modeling the mechanics of the cardiovascular system* (with Prof. Gerhard Holzapfel)

## Outreach

- **X. Cai**. *Bridging the gap between computational scientists and HPC*. Article published in Meta, Number 3, 2007.
- **R. E. Bredesen** and **G. T. Lines**: *"KoMiN – Annual conference for Norwegian math students at all levels"*. Presentation of the work done at CBC and recruiting new promising talents among the 50 attendants; November 2-3, 2007
- **P. R. Leinan, K. Valen-Sendstad, O. C. Myklebust** and **S. K. Dahl**: *Trondheim Technoport 2007*. CBC participated at the Trondheim Technoport Exhibition, displaying new technology and advanced computer modelling of processes within the human body for the 10.000 visitors to the exhibition; October 18-20, 2007
- **B. F. Nielsen**, O. M. Lysaker and **M. Larson**. Can inverse problems tell you the condition of your heart? *Zurich Intelligencer*; International Congress on Industrial and Applied Mathematics (ICIAM), Springer, Pages 38-40, 2007.

## Releases of Software Packages

In 2007, we released stable versions of the following software:
- UFC 1.0
- Swiginac 1.0

We also made significant progress with the following packages: Instant 0.9; DOLFIN 0.7; FFC 0.4; SyFi 0.4 and Viper 0.1.

# LIST OF INTERNATIONAL GUESTS

*Norwegian visitors are not listed, but count more than 40.*

| Period | Name | Affiliation | Nationality |
|---|---|---|---|
| Nov 29 | Kristoffer Selim | Chalmers University of Technology | Swedish |
| Nov 14-15 | Prof. Patrick Segers | Ghent University Hospital | Belgian |
| Nov 14-15 | Abigail Swillens | Ghent University Hospital | Belgian |
| Nov 08 | Prof. Didier Clamond | University of Nice | French |
| Oct 29-31 | Dr. Luca Antiga | Mario Negri Institute for Pharmacological Research | Italian |
| Oct 22-26 | Prof. Christoph Pflaum | Friedrich Alexander University | German |
| Oct 24 | Prof. Sverker Holmgren | University of Uppsala | Swedish |
| Oct 24 | Jacko Koster | Uninett Sigma | Dutch |
| Oct 24 | Mario Martinez-Zarzuela | University of Valladolid | Spanish |
| Oct 7-20 | Dr. Geoff Bohling | Kansas University | American |
| Oct 4 | Prof. Victor Haughton | University of Wisconsin | American |
| Oct 1 | Ismail Aricigil | UiO | Turkish |
| Oct 1 | Dr. Andres Brandbruck | CMA | Estonian |
| Oct 1 | Dr. Mattias Sandberg | CMA | Swedish |
| Oct 1 | Peter Schmutzeler | UiO | Duch |
| Sep 25-Oct 10 | Dr. Lin Chen | Hohai University | Chinese |
| Sep 25-Oct 10 | Prof. Wen Chen | Hohai University | Chinese |
| Sep 25-Oct 10 | Hongguang Sun | Hohai University | Chinese |
| Sep 25-Oct 10 | Xiaodi Zhang | Hohai University | Chinese |
| Sep 10-14 | Fred Lionetti | University of California, San Diego (USCD) | American |
| Sep 06 | Dr. Kirsten ten Tusscher | Utrecht University | Dutch |
| Jun 19-21 | Lucie Trouve | Star-CD | French |
| Jun 18-19 | Prof. Garth Wells | Delft University of Technology, | Australian |
| Jun 13-14 | Prof. William K. George | Chalmers University of Technology | Swedish |
| Jun 15 | Dr. Robert Artebrand | ETH Zurich | Swedish |
| Jun 11-13 | Christer Ahlstrøm | University of Lindköping | Swedish |
| Jun 11-15, Oct 21-26 | Prof. Scott Baden | University of California | American |
| Jun 11-13 | Dr. Bindi Brook | University of Nottingham | British |
| Jun 10-12 | Prof. Per Ask | Lindköping University | Swedish |
| Jun 10-14 | Dr. Simone Deparis | École Polytechnique Fédérale De Lausanne | Switzerland |
| Jun 10-13 | Novak Elliot | University of Warwick | Australian |
| Jun 10-13 | Dr. Nils-Erik Hörlin | KTH, Stockholm | Swedish |
| Jun 10-14 | Dr. Tiina Roose | University of Oxford | Estonian |
| Jun 10-12 | Prof. Robert Schroter | Imperial College London | British |
| Jun 10-13 | Dr. Sarah Waters | University of Nottingham | British |
| Jun 10-13 | Dr. Robert Whittaker | University of Nottingham | British |
| Jun 9-13 | Dr. Sevil Payvandi | Imperial College London | British |
| Jun 9-13 | Dr. Jennifer Siggers | Imperial College London | British |
| Apr - June | Ryan Dean | University of Saskatchewan | Canadian |
| Jun 7-14, Oct 1 | Dr. David Drazen | University of Oslo | American |
| Jun 7-14, Dec 16-20 | Prof. Robert C. Kirby | University of Texas | American |
| Jun 7-14 | Mathilda Lindèn | Chalmers/FFI | Swedish |
| Jun 7-14 | Dr. Hari Radhakrishnan | FFI/University of Cyprus | Crete |
| Jun 7-14 | Dr. Murat Tutkun | Chalmers/FFI | Turkish |
| Jun 7-14 | Dr. Maja Wänström | Chalmers/FFI | Swedish |

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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