

# **The DFG research center “Mathematics for key technologies” How it began and where it is heading**

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## **NOW OR NEVER**

In the early afternoon of November 12, 2001, the “final meeting” of the main authors of the application for a DFG research center started in a crowded seminar room of the mathematics building of TU Berlin. It was clear to everybody that this was a decisive moment. Either we get it right that day or we will never have a center. Tension was high, air sticky, and there was no way to postpone a decision. The meeting ended at midnight – due to mental and physical exhaustion. One of the initiators of the center, however, and the editorial assistant continued. They incorporated all the corrections and text revisions agreed on. They finished at 4:22 a.m., November 13, with an e-mail to everybody involved. The subject line was “**burn-out release 1.0**”. Another member of the team of writers got up at 5:00 a.m. and checked the changes. Then the 412 pages (or 59 MB) application book, signed by the presidents/directors of FU, HU, TU, WIAS, and ZIB, was sent to the printer. Thirty four printed books were shipped by express mail to the Deutsche Forschungsgemeinschaft (DFG) in Bonn on November 14 shortly after noon to meet the November 15 deadline.

These days were the most hectic phase of the application procedure for the DFG research center. The process began with a decision of the Senate of the Deutsche Forschungsgemeinschaft on October 26, 2000, to establish such centers and ended (for us joyously) on May 8, 2002, when the DFG Hauptausschuss decided to grant the research center to the Berlin initiative.

In this article I would like to outline what the intentions behind the center idea are, how one applies for such a center, what the applied mathematicians from Berlin have in mind, and where they are heading.

Before going into the administrative and organizational details I want to introduce the new DFG research center by quoting the executive summary (pages i–iii of the application book mentioned above). It took us a long time to make it short.

### **Executive summary**

#### **Mathematics for key technologies:**

#### **Modelling, simulation, and optimization of real-world processes**

Key technologies become more complex, innovation cycles get shorter. Flexible mathematical models open new possibilities to master complexity, to react quickly, and to explore new smart options. Such models can only be obtained via abstraction. This line of thought provides our

global vision: Innovation needs flexibility, flexibility needs abstraction, the language of abstraction is mathematics. But mathematics is not only a language, it adds value: theoretical insight, efficient algorithms, optimal solutions. Thus, key technologies and mathematics interact in a joint innovation process.

The mission of the Center is to give a strong push to the role of mathematics in this interactive process. The Center's research program is application-driven. Its implementation will have a strong impact on the development of mathematics itself and will define a new stage of inter- and transdisciplinary cooperation.

Building upon the special strengths of mathematics in Berlin, the following fields will be involved:

- I Optimization and discrete mathematics
- II Numerical analysis and scientific computing
- III Applied and stochastic analysis

Building upon existing cooperations, the following key technologies are to be addressed in the first 4-year period:

- A Life sciences (computer-assisted surgery; patient-specific therapies; protein data base analysis; protein conformation dynamics)
- B Traffic and communication networks (planning of multi-level and multi-layer communication networks; planning of the UMTS radio interface; line planning, periodic time-tabling, and revenue management in public transport)
- C Production (shape memory alloys in airfoils; production of semiconductor crystals; methanol fuel cell optimization; online production planning)
- D Electronic circuits and optical technologies (quantum mechanical modelling of optoelectronic devices; design of nano-photonic devices; integrated circuits for future chip generations)
- E Finance (measurement and hedging of risks; interaction models for asset price fluctuation)
- F Visualization (discrete differential geometry; image processing)

While these application areas seem quite disjoint in real terms, the mathematical approach to major questions in these diverse areas brings out common structures. Analysis, stochastics, and discrete mathematics supply conceptual frames in these areas. Numerical mathematics and optimization provide the algorithmic machinery that enables the quantitative solution of a wide range of real-world instances. Even though the existing expertise has been highly successful in quite a few practical applications, it has not yet reached the level of competence needed to cope with many of the challenges of current technology. In order to increase this level of competence, we apply for the DFG research center "Mathematics for key technologies" as an institutional basis for a major joint effort in the direction of modelling, simulation, and optimization of real-world processes.

The Center will also radiate to mathematical education on all levels, see the projects in area

#### G Education

This includes graduate and undergraduate education at our universities, e. g., via new interdisciplinary study programs and new types of courses. Beyond that level, the Center will support advanced training courses for high school teachers and students bringing mathematical modelling and real-life applications into the classroom.

Institutionally, the Center will be led by the

- o Institut für Mathematik, Technische Universität Berlin (TU)

in cooperation with

- Fachbereich Mathematik und Informatik, Freie Universität Berlin (FU)
- Institut für Mathematik and Institut für Informatik, Humboldt-Universität zu Berlin (HU)
- Weierstraß-Institut für Angewandte Analysis und Stochastik Berlin (WIAS)
- Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB)

From these institutions, almost 30 senior mathematicians contribute to the proposal, all of them renowned for their research and, in particular, for their significant contributions to the modelling and solution of a wide range of real-world problems. In addition, almost the same number of junior scientists take responsibility as project leaders.

The coordination committee consists of

- P. Deufhard (FU and ZIB)
- H. Föllmer (HU)
- M. Grötschel (TU and ZIB, designated coordinator)
- V. Mehrmann (TU)
- J. Sprekels (HU and WIAS)

The administration and main activities of the Center will be located on the third floor of the TU mathematics building.

#### UMTS AND DFG RESEARCH CENTERS

In August 2000, the German government sold licenses to offer third generation cell-phone service (UMTS) by an auction that attracted international interest. The total revenue was spectacular: about 50 billion Euros. Part of the auction earnings went to the Bundesministerium für Bildung und Forschung (BMBF) that, in turn, increased its support of the DFG.

The DFG decided to use some of this additional funding to start a new coordinated program: DFG research centers. The aim of the program is described in the first paragraph of the resolution of the DFG Senate of October 26, 2000:

Ziel des Programms ist es, in deutschen Hochschulen in begrenzter Anzahl international sichtbare und konkurrenzfähige Forschungszentren zu etablieren. Diese Zentren sollen wichtiger Bestandteil der strategischen und thematischen Planung einer Hochschule sein, ihr Profil deutlich schärfen und Prioritäten- bzw. Posterioritätensetzung verlangen. Die Konzentration von Exzellenz, Ressourcen und Kompetenz soll unter anderem durch die Anfinanzierung und Ausstattung von Professuren durch die DFG erreicht werden, deren spätere Übernahme einen wichtigen Beitrag der Grundausstattung darstellt.

#### THE FIRST ROUND OF PROPOSALS: HIGH SPEED

Although aiming at highest standards, at international visibility and competitiveness there was almost no time left to breathe deeply before starting to write. The DFG expected the universities to submit proposals within eight weeks. Another quote from the resolution:

Es wird um Konzepte (ca. 25 Seiten) für die Gründung eines konkreten Zentrums gebeten, dem bereits eine wissenschaftlich exzellente und das Profil der Hochschule prägende Struktur zugrundeliegt, welche mit den durch das Programm der DFG-Forschungszentren angebotenen Möglichkeiten ausgestaltet werden soll. Diese Konzepte, die in einer ersten, nicht thematisch definierten Auswahlrunde berücksichtigt werden sollen, müssen bis zum 20. Dezember 2000 in der Geschäftsstelle der Deutschen Forschungsgemeinschaft eingetroffen sein. Der Senat wird darüber entscheiden, welchen Initiativen danach eine Antragstellung ermöglicht wird.

By Christmas 2000, more than 80 proposals had reached the DFG. They came from all parts of the country and ranged over all areas of engineering, the sciences, and the humanities. Considering the side constraints, the time frame, and the fact that this was a completely new program, this result surprised everybody.

One of the proposals was written by a group of applied mathematicians from FU, HU, TU, WIAS, and ZIB. It was formally submitted to DFG by the president of TU on December 19, 2000.

#### RESULTS OF THE FIRST ROUND

Making reasonable decisions on such a large number of heterogeneous applications is an imposing task. The DFG decided to invite seven (quite diverse) proposals to present fully-fledged applications. Forty two applications (including our proposal) received a positive vote and were put on hold for further consideration. Over 30 proposals were rejected.

Three of the seven selected proposals finally won a research center. These centers were established in 2001: "Ocean rims" in Bremen, "Functional nanostructures" in Karlsruhe, "Experimental biomedicine" in Würzburg.

#### THE SECOND ROUND

While handling the seven finalists the DFG sent out a call for new proposals. This time proposals were invited that focused on one of two particular (though broad and transdisciplinary) areas. One of the topics selected by the DFG was *Modellierung und Simulation in den Natur-, Ingenieur- und Sozialwissenschaften*. The Berlin applied mathematicians decided to try again and submitted a polished and enhanced version of the previous proposal. The deadline was April 25, 2001. The DFG specified criteria for the selection, I quote:

- (1) Research quality
- (2) Extent of cooperative financial support obtained so far (from the DFG and other supporting institutions)
- (3) International visibility of the site
- (4) Utilizing the possibilities of the program to structure the development of the university and to focus on research areas
- (5) Importance for young scientists
- (6) Originality of the submitted project compared to other current supported activities

Fourteen proposals from a wide range of groups covering, e.g., engineering, computer science, biochemistry, and medicine reached the DFG by April 25. Many applications were interdisciplinary, some involved colleagues from mathematics. Our proposal was the only one focusing on mathematics.

#### THE REAL APPLICATION

On July 17, 2001, we learned that we were among the three finalists. This was within the last week of the Berlin summer semester, and everybody was heading for conferences or vacation, a really bad time to meet each other, to brainstorm together, and to discuss how to proceed. At the end of August 2001, the preparation of the full application started. Within two and a half months about 50 mathematicians in Berlin found a joint vision for their future work, coordinated their research projects, and agreed on many details so that a streamlined application with a clear goal and focus arose. Considering that, in mathematics, it is rather unusual that such a large group works together in a very short period of time this was a formidable achievement. We did not only have to streamline our mathematical thoughts, five institutions had to be convinced to actively support the project. Many of us had to attend quite a number of meetings with representatives and committees of all kinds. The result was extremely positive. After brief explanation, unanimous support came from all academic institutions involved.

The Deutsche Forschungsgemeinschaft also expected financial support from the State of Berlin. This was (sort of) granted initially, but the promise never materialized. To fill the financial gap the five academic institutions jointly made a substantial effort to match what the DFG expected from the participating institutions and the host state of the research center. All in all, this process showed that the academic institutions in Berlin are able to act, to define priorities, and to move forward in a joint and coordinated way.

#### THE FINAL SELECTION

The submission of the application mentioned in the beginning of this article was not the final word. On January 21 and 22, 2002, each of the three finalists had half a day to present the application orally and visually to DFG representatives and an international group of reviewers appointed by the DFG. Eighteen persons, including representatives from all participating institutions and the State of Berlin, travelled to Bonn, gave thirteen short presentations, and passed the detailed interrogation by the “examiners” with distinction.

The DFG Hauptausschuss finished the competition on May 8, 2002, and declared our application the winner. The new center took up operation on June 1, 2002.

Since the rule of the “center game” is *The winner takes it all*, the DFG decision yielded many disappointed runners-up who had spent as much energy on their application as we did.

## THE INITIAL PHASE OF THE CENTER

The center is still, at the time of writing, in its initial phase of operation. We are working on the bylaws of the center, a cooperation treaty between all institutions involved, and all other kinds of legal aspects of an organization of this type. Hiring is in full phase, and we are glad that many excellent colleagues have applied to the new positions offered in the center.

## STATISTICS

The annual financial support from the Deutsche Forschungsgemeinschaft is about 5 million Euros. The Berlin institutions provide additional annual support of about 3 million Euros. Six new professor positions will be created from the DFG funds, as well as seven junior research groups. About 70 new researchers will be employed plus roughly 30 student research assistants, some technicians, and administrative staff. The Berlin universities have declared more than 30 professor positions as structurally important for the center. They guarantee their existence for the lifetime of the center and have promised speedy handling of all hiring and other administrative processes necessary. This will create a research infrastructure in mathematics unparalleled in Germany.

The current grant for the DFG research center is given for four years. The center can reapply twice, and thus, it has a maximum life time of twelve years. We do hope that we will achieve this “finishing line”, and that at this point, we will have established a *center* that lives on its own, is well known in the world through its scientific contributions and success, and forms an integral part of the lively Berlin research-and-technology scenario.

## COOPERATION

The center is not just a mathematical research institution. It aims at cooperation with other sciences, engineering, management science and economics, and in particular, with partners in commerce and industry that are active in the key technologies the center is determined to address. The DFG research center “Mathematics for key technologies” is open for discussion and invites proposals for cooperation.

This booklet contains a few surveys about the research that will be carried out in the center. The articles show where we are starting from, outline where we are heading at, and what type of applications we envisage. We hope that some readers feel encouraged to contact us.

## FURTHER INFORMATION

The center has just begun to design and develop its web presentation. If you have further interest in the center, its work, its projects, talks, workshops, or job openings please consult our web site at:

<http://www.math.tu-berlin.de/DFG-Forschungszentrum/>