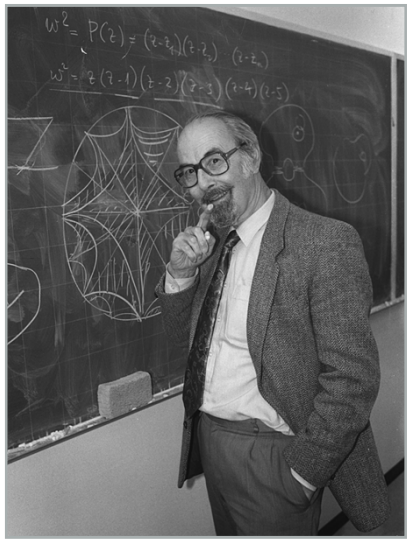
THE TASK AHEAD
Reflexions on the future of mathematics

by Henrik Martens (around 1990)



and by

Helmut Neunzert
Fraunhofer-Institute for
Industrial Mathematics ITWM

25 years later

Copenhagen, 21st May 2014

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We are witnessing an increasing invasion of mathematics and mathematicians into the engineering environment.

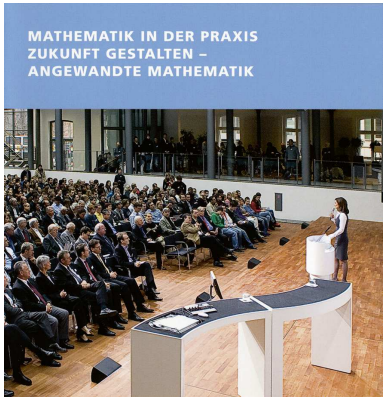
HOW DO WE PREPARE OUR STUDENTS FOR SUCH TASKS?

Mathematics enters engineering

as a DISZIPLINE

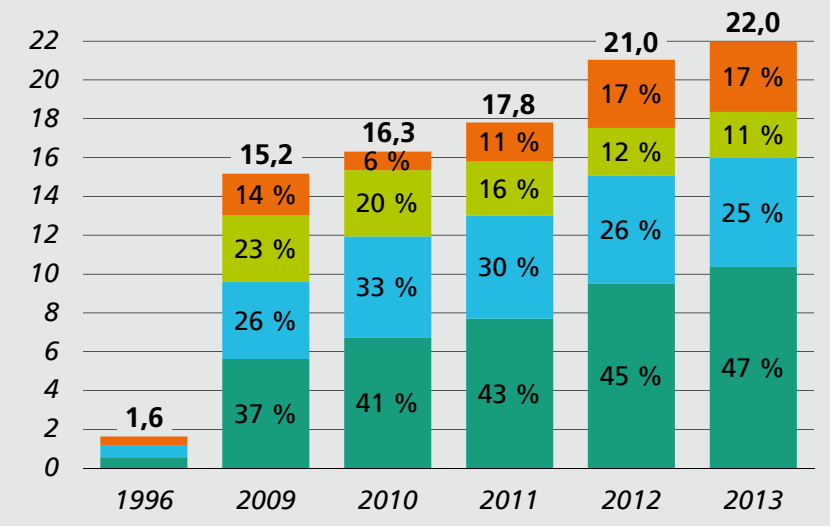
as a PROFESSION

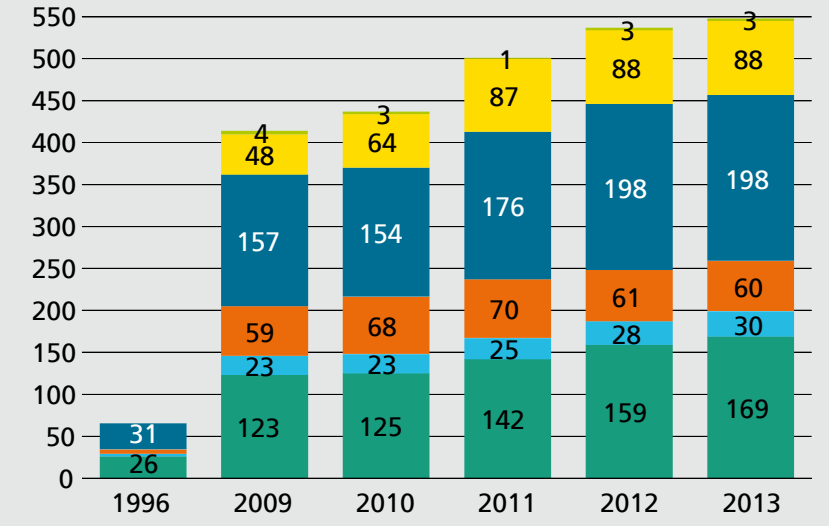
as an EDUCATIONAL TASK



ITWM in numbers

Operating budget [Mio €] and personnel





- Base funding
- Fraunhofer internal programs
- Public projects
- Industry

- Apprentices
- Trainees
- Research assistants
- PhD students
- Central services
- Scientists/Technicians

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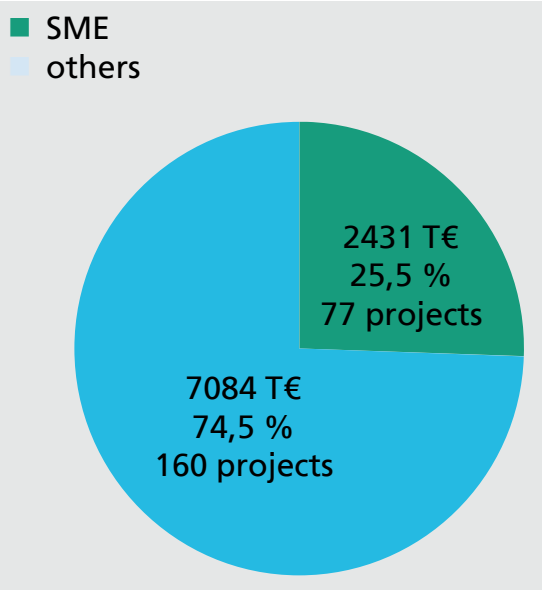
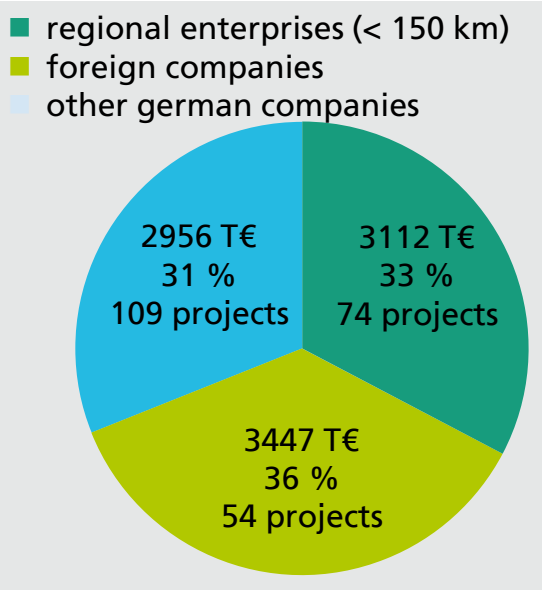
Spreading of Industrial Earnings in 2013
Total: 10.37 Million € with 264 projects





Largest customers:

Statoil	888 389 €
Siemens	491 149 €
DZ Bank	468 000 €
Daimler	447 267 €
BASF	434 730 €

- Industrial partners (total): 153
- Industrial projects: 237
- Follow-up projects: 79
- New partners: 50

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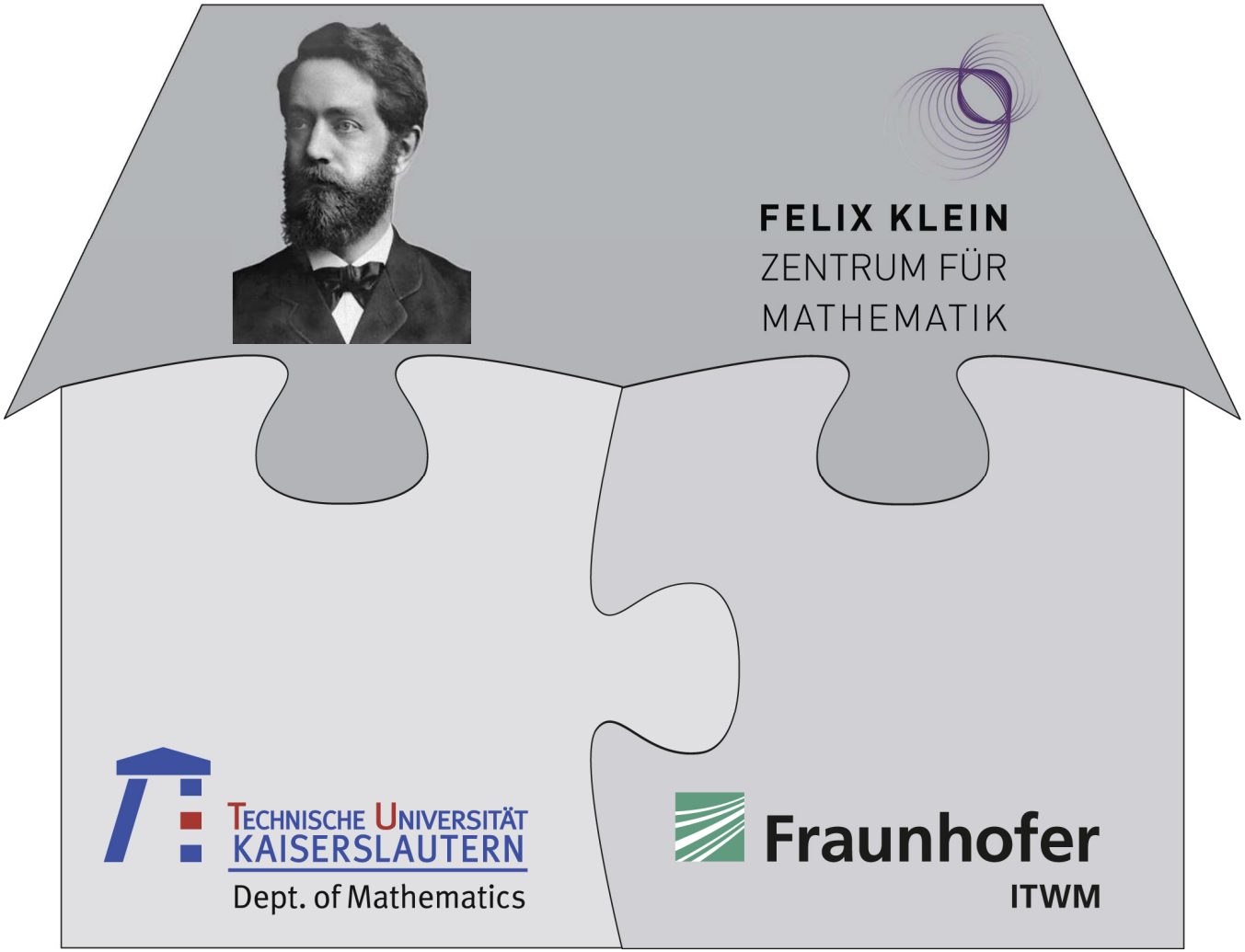
FELIX KLEIN
ZENTRUM FÜR
MATHEMATIK
TECHNISCHE UNIVERSITÄT
KAISERSLAUTERN
Dept. of Mathematics
Fraunhofer
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Industrial mathematicians at OSRAM (1924)

Staatsbibliothek Berlin, Nachlass Runge, Depositum 5, p. 754

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Archimedes

"The first recorded instance of industrial mathematics occurred more than 2000 years ago in Syracuse when Archimedes ran naked through the streets yelling Eureka."

Mathematics as a discipline:
Henriks “predictions“

■ Galois fields	→	error-correcting codes
■ Formal logic	→	digital switching systems
■ Abstract algebra	→	linear systems
■ Algebraic geometry	→	nonlinear systems
■ Prime number theory	→	cryptography
■ Gödels and Turings work	→	computer science
■ Harmonic and complex analysis and operator theory	→	control theory and signal analysis

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Mathematics as a discipline:
An important area for future application

- Prediction:
  We will see a rapidly growing alliance between mathematics and medicine
- Example 1: Medical Imaging
  (see “More Mathematics into Medicine“ by P. Deuflhard, O. Dössel, A. K. Louis, S. Zackov, 2009)

Computational Tomography (CT)
Abdomen mit Rippenanschnitten

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Mathematics as a discipline: Mathematics in medicine
Example 1: Medical imaging

Magnetic Resonance Imaging (MRI)
Sagittaler Schnitt durch einen Kopf

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Mathematics as a discipline: Mathematics in medicine
Example 1: Medical imaging

Schlagende
Herzklappe

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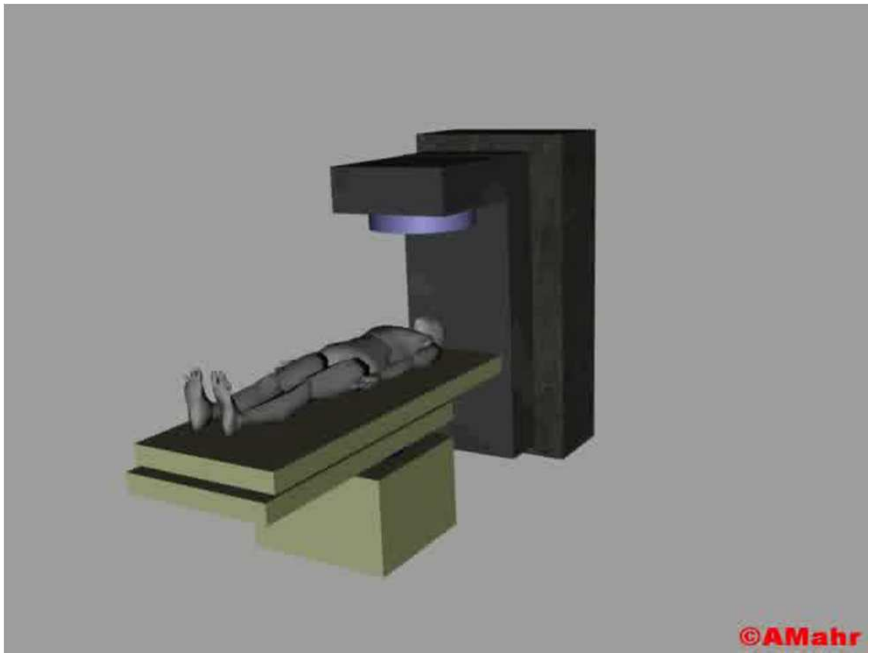
Mathematics as a discipline: Mathematics in medicine

- Prediction:
  We will see a rapidly growing alliance between mathematics and medicine
- Example 2: Therapy planning (Dept. of Optimization, ITWM)
  - Radiation therapy:
    most important cancer treatment besides surgery and chemotherapy
  - Physical modalities:
    photons, protons, heavy ions
  - Therapy goals:
    destruction of tumor cells with high doses, simultaneous sparing of healthy tissue
  - Intensity modulation (IMRT): temporary and partial blocking of emitted radiation



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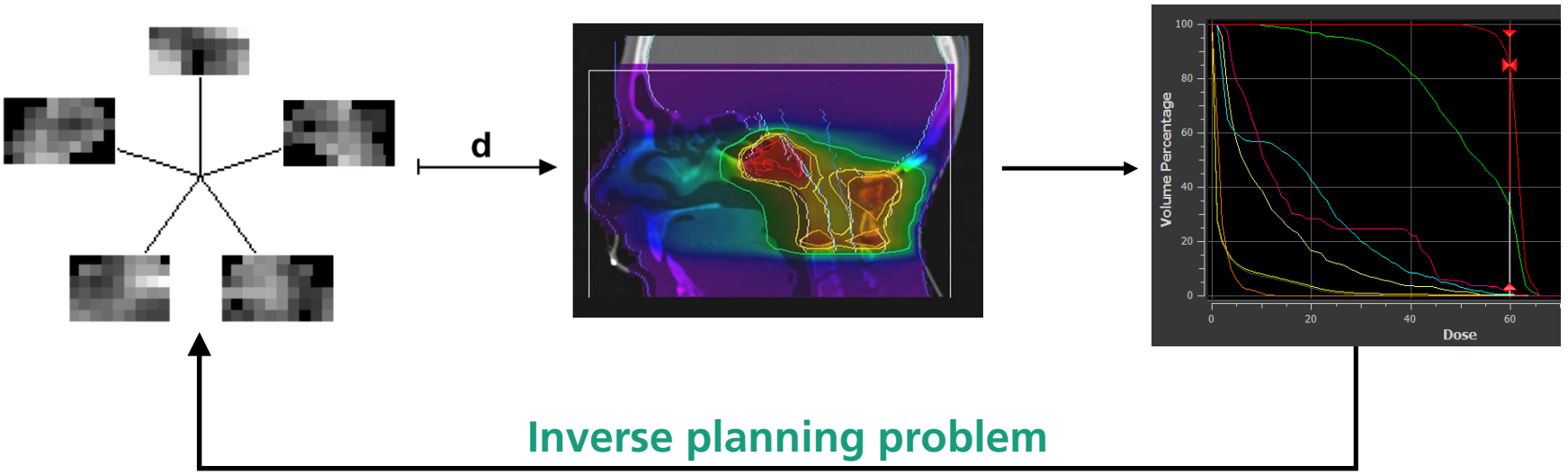
Mathematics as a discipline: Mathematics in medicine
Example 2: Therapy planning

Therapy plan | **Dose distribution** | **Plan quality**



Intensity values on ~10^3 beamlets and ~10 beams

Dose values on ~10^6 voxels

Criteria on organ dose, dose statistics, isodose display

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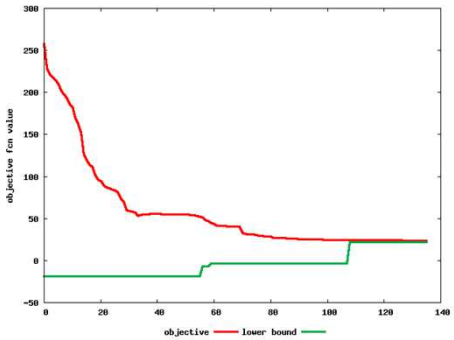
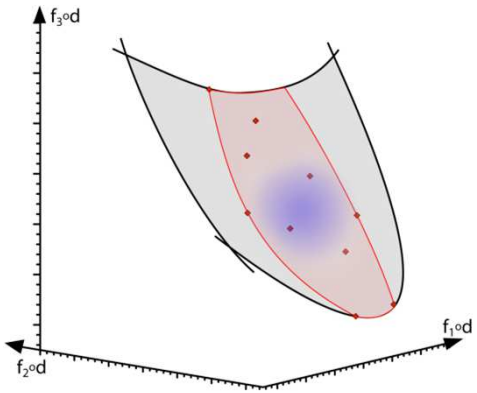
Mathematics as a discipline: Mathematics in medicine
Example 2: Therapy planning

Numerical solver



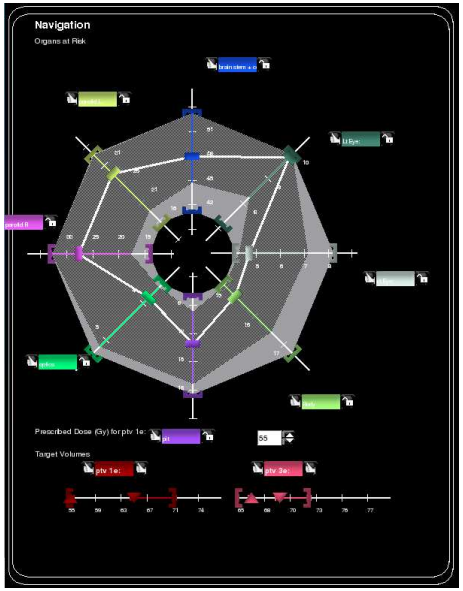
Efficient nonlinear optimization method with duality control

Pareto approximation



Sandwiching algorithm for multi-criteria convex optimization problems

Decision support



Interactive value search on criteria based on plan interpolation

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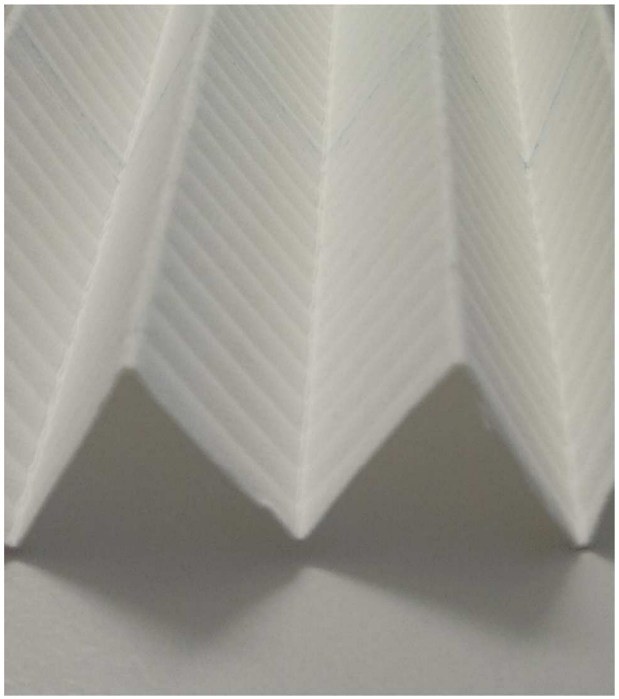
Mathematics as a discipline:
Filtration processes

- Example: Modeling and simulation of filtration processes (Dept. of Flow and material simulation (Oleg Iliev, ITWM)



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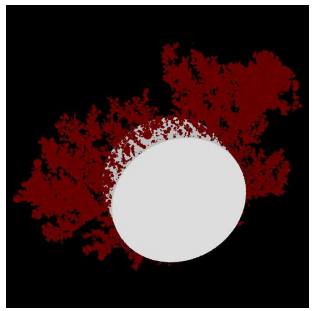
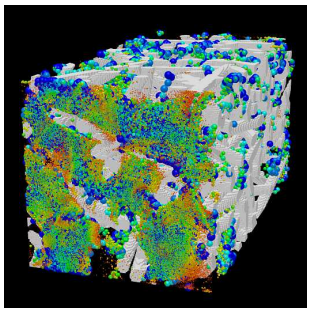
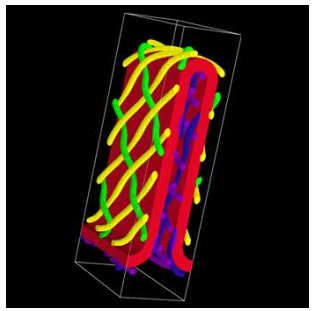
Mathematics as a discipline:
Filtration processes

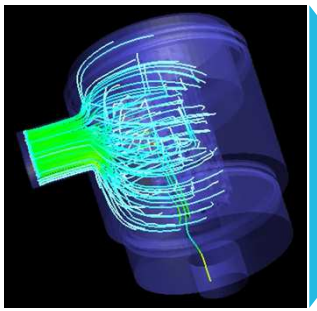
Multiple scales

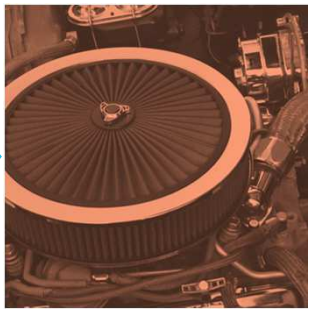
Particles level Nano scale	**Filter components** Micron scale	Millimeter	**Filter element** Centimeter	**Complete system** Meter











Fiber Nanometer	**Media** Micrometer	**Pleat** Millimeter	**Element** Centimeter	**System** Meter

(Navier-)Stokes(-Brinkman) plus Stochastic ODE for particles

Navier-Stokes-Brinkman plus Concentration CDR for particles

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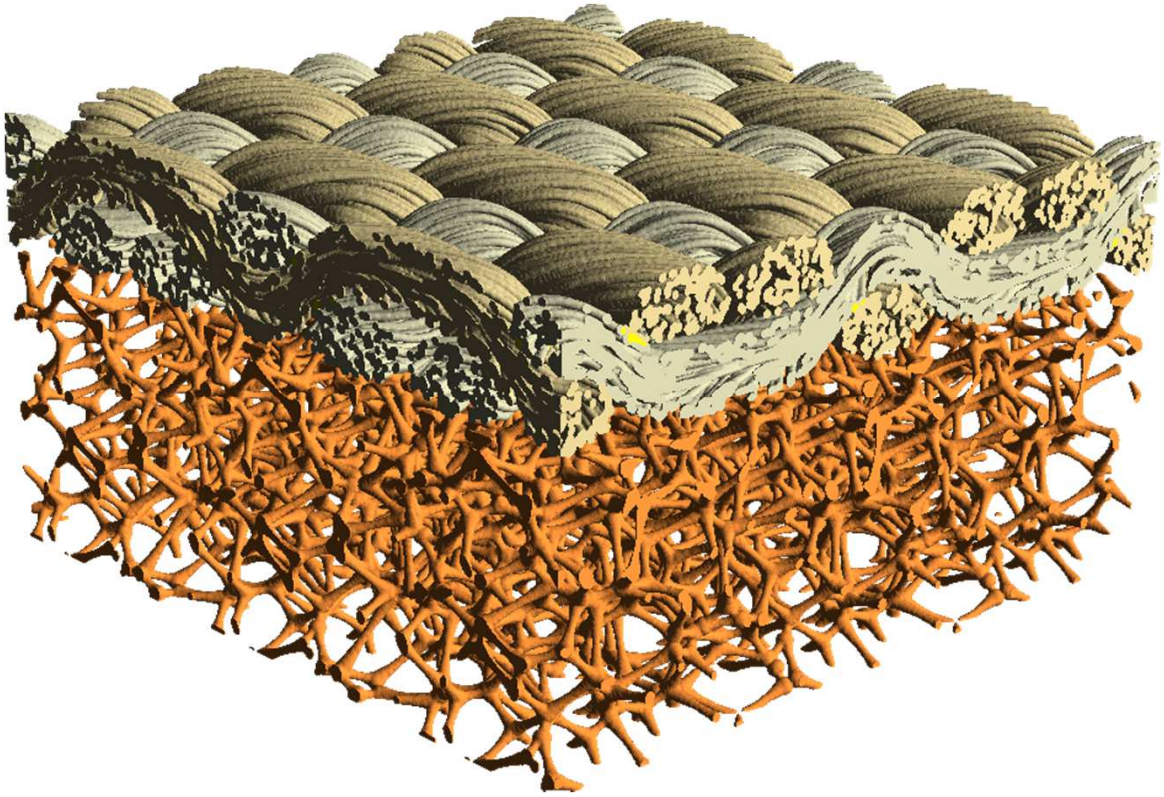
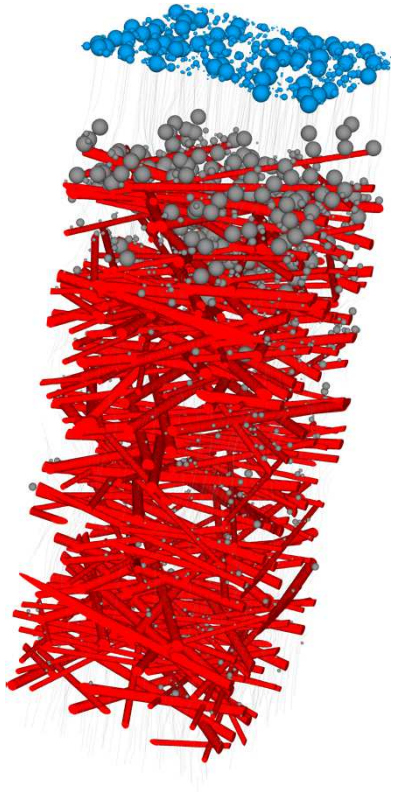
Mathematics as a discipline:
Filtration processes

The pore scale





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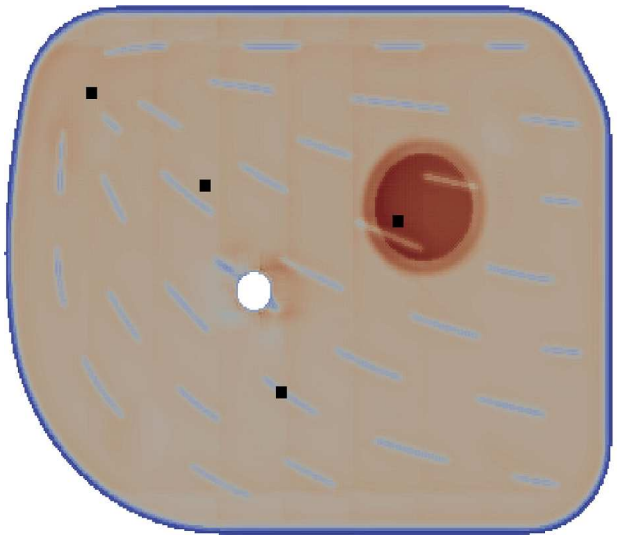
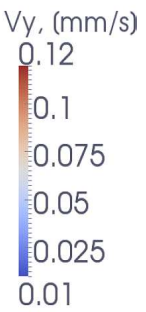
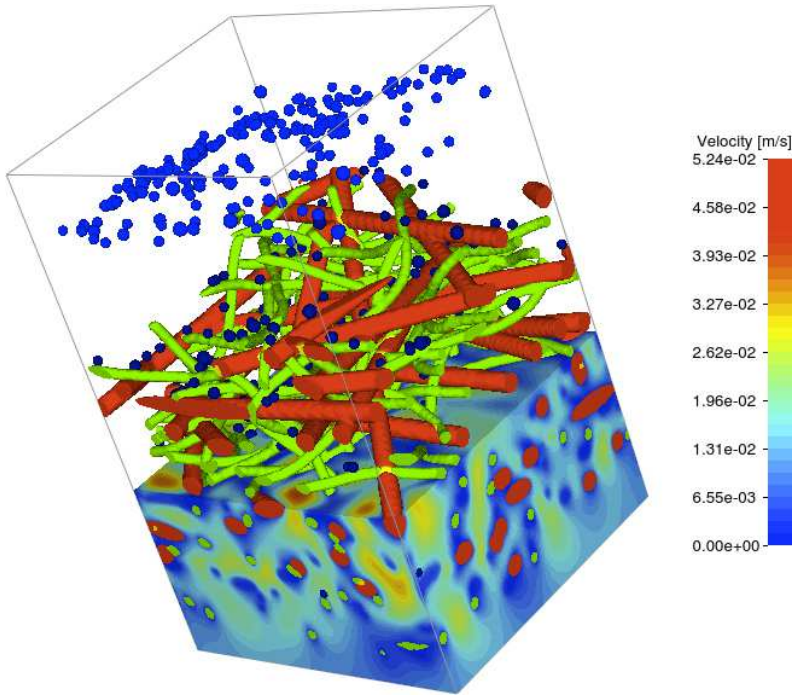
Mathematics as a discipline:
Filtration processes

Multigrid and multiscale







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Mathematics as a discipline:
Filtration processes

A. A. Samarskii
(1919 - 2008)

Model – Algorithm – Program

The computer experiment =

Model + Algorithm + Programme

M A P

+ Visualization

= Simulation!

"A new scientific method, which determines the style of thinking of a modern scientist as well as the kind of problems he is able to attack."

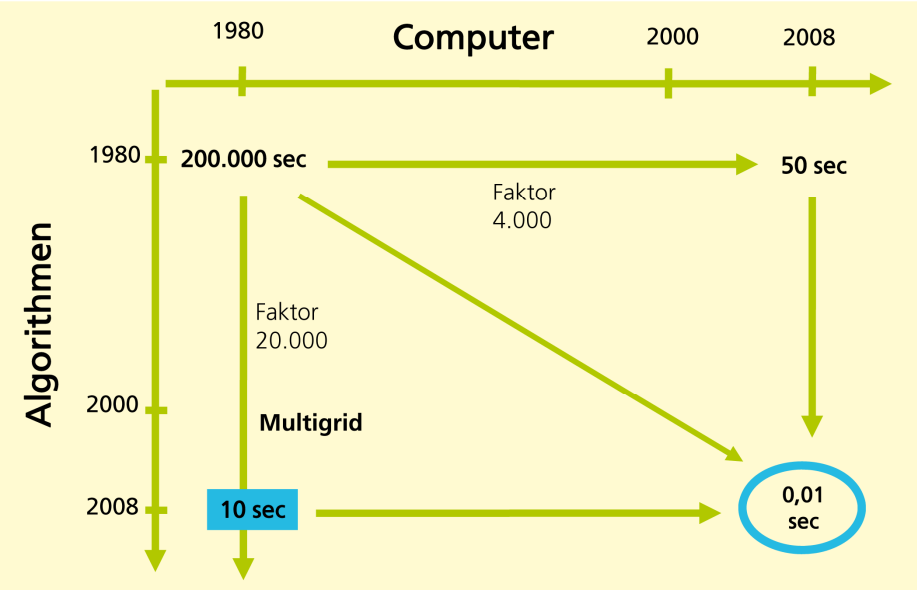
Mathematics as a discipline:
A second prediction

- Prediction: Applied mathematics will become more and more a

  “Head craft for handicraft”

- Even basic technologies require advanced mathematics for modelling, numerics and implementation

Mathematics = Modelling + Numerics + Implementation



Algorithms versus hardware:

Example:
Heat transfer / diffusion equation

Mathematics as a profession

A. Giacometti
Man pointing,
MoMA, New York,
Photo: S. Mährlein

To market “mathematics as a technology“ one needs

- to be trustworthy
- to listen carefully what the customer really wants
- not to solve academic

but

- to solve the industrial problem

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Mathematics as a profession
Archimedes

"The first recorded instance of industrial mathematics occurred more than 2000 years ago in Syracuse when Archimedes ran naked through the streets yelling Eureka."

"We may well see the emergence of industrial mathematics as member of a new technological profession, solidly rooted in the mathematical sciences, but with its own professional profile and goals."

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Mathematics as a profession
Teamwork

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Mathematics as a profession

“What is complicated to simulate is the cooking of an omelette“
(J. L. Lions)

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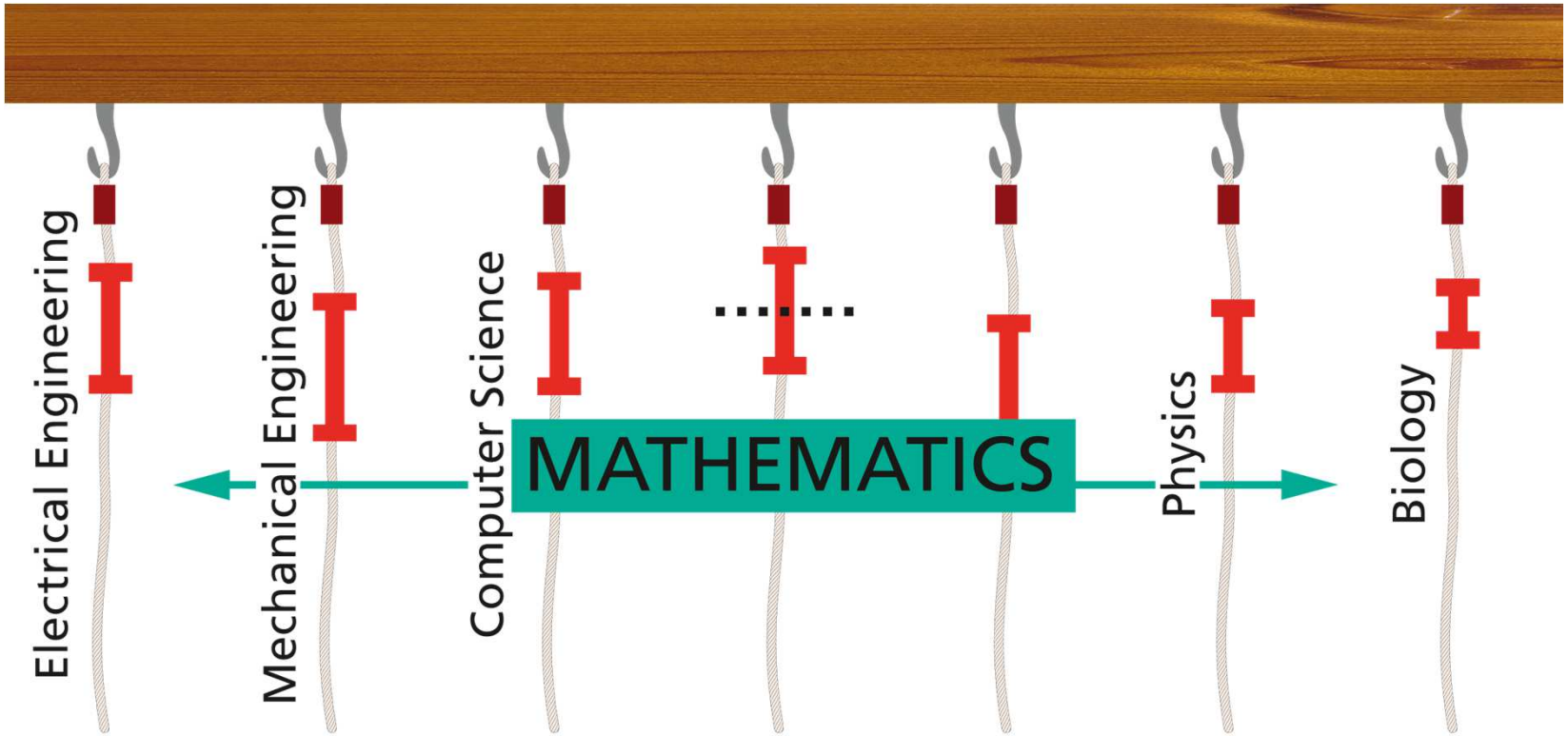
Mathematics as a profession
Transversal thinking



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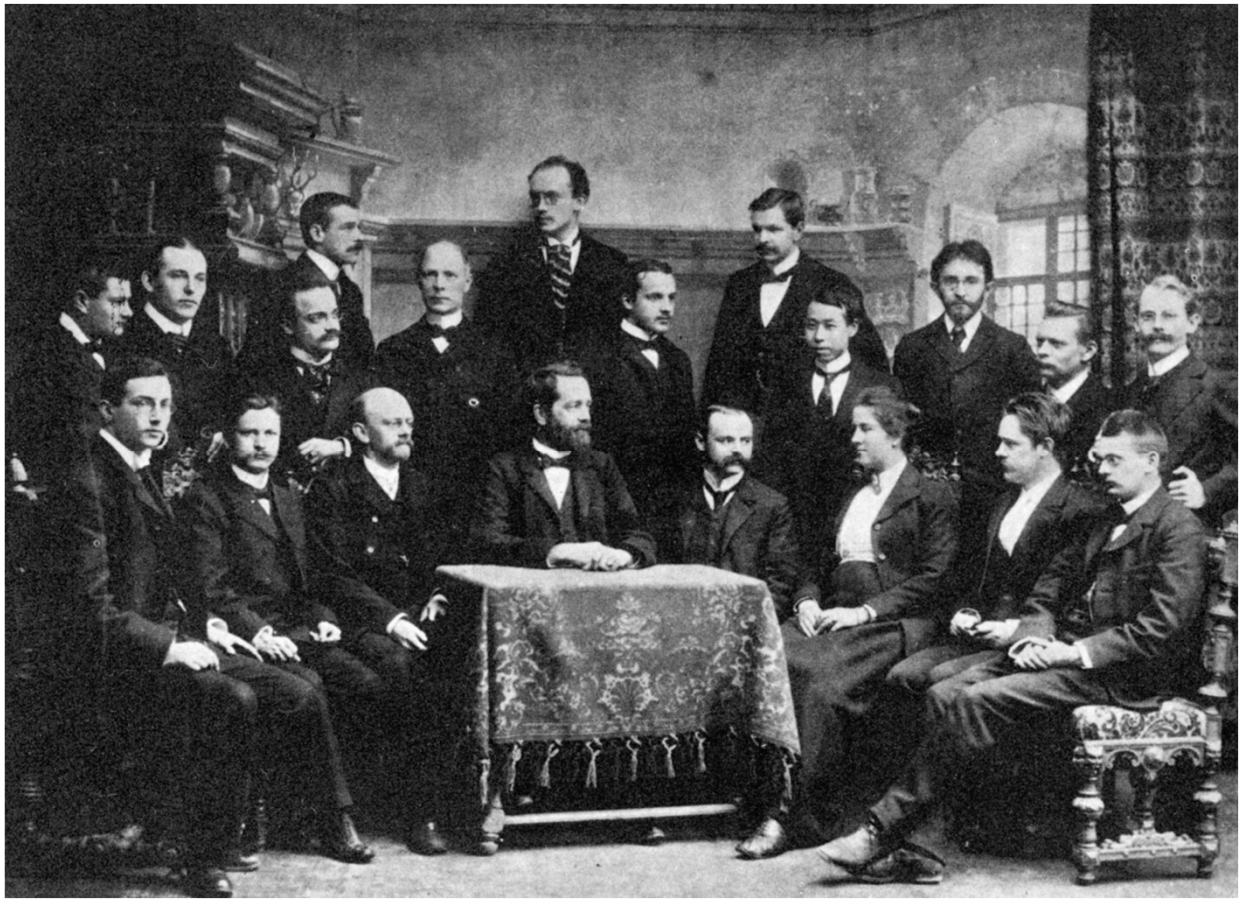
Mathematics as an educational task
Hilbert, Klein in the Mathematicians Club, Göttingen 1902



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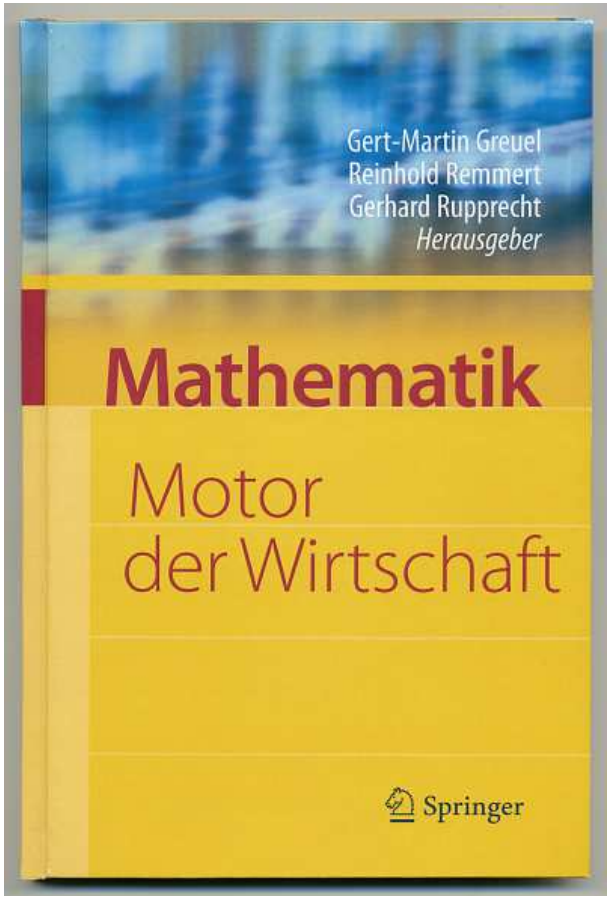
Mathematics as an educational task
Impressions from a “Modelling week”

FELIX KLEIN
ZENTRUM FÜR
MATHEMATIK

The task ahead
“Mathematics, the engine for economy“



- herausgegeben von »Oberwolfach«, Springer April 2008
- Initiative der Wirtschaft zum »Jahr der Mathematik 2008«
- Texte der Vorstandsvorsitzenden von Allianz, Bayer, Böhringer Ingelheim, Daimler, Deutsche Bank, Deutsche Börse, Dürr, IBM, Infineon, Linde, Lufthansa, Münchner Rück, RWE, SAP, Siemens, TUI

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The task ahead
Citations from “Mathematics, the engine for economy“

- *“As no other science, Mathematics helps in our trade to solve many kinds of problems – and exactly this universal applicability is responsible for Mathematics to be the Queen of all disciplines.”* (D. Zetsche, CEO Daimler)
- *“Permanent changes determine the competition and its conditions. But yet there is a constant, which keeps everything together and which is an important building stone for innovation: Mathematics.”* (M. Jetter, former CEO, IBM Germany)
- *“Without mathematics, a successful risk management is not possible.”* (R. Francioni, CEO, Deutsche Börse)
- *“Management without Mathematics is like space travel without Physics. Numbers are not everything in business life. But without Mathematics almost everything is nothing here.”* (H. Kagerman, former CEO, SAP)
- *“Mathematics – that is the language of science and technology. Therefore, it is the driving force behind all high technologies and a key discipline for all industrial nations.”* (P. Loescher, former CEO, Siemens)

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