European initiatives for Industrial Mathematics – a global perspective

Final presentation at ESGI-95, Sofia

Wil Schilders
Past president of the European Consortium for Mathematics in Industry (ECMI)

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

Congratulations!

- **On behalf of ECMI, I would like to congratulate the organisers, problem owners, sponsors and participants of the first Bulgarian Study Group**

Growing importance of mathematics

- **The mathematical sciences play a vital part in all aspects of modern society.**
  - Without research and training in mathematics, there would be no engineering, economics or computer science; no smart phones, MRI scanners, bank accounts or PIN numbers.
  - Mathematics is playing a key role in tackling the modern-day challenge of cyber security and in predicting the consequences of climate change.
  - The emergence of truly massive datasets across most fields of science and engineering increases the need for new tools from the mathematical sciences.
  - Innovations are impossible without the use of virtual design environments that enable engineers to develop and test their complex designs behind a screen, without ever having to go into the time-consuming (several months) process of prototyping.
- **Increased awareness by society and industry that mathematical simulation is ubiquitous to address the challenging problems of our times.**

A new way of working in industry

- **Globalisation**
- **Awareness of resource limitations**
- **Increasing sensitivity to anthropogenic effects on the environment**
- **General concerns about sustainability**

- **All of these impose constraints on industry, as well as on society as a whole**
- **They force industry to continually analyse and evaluate its activities in a broader social context, beyond the bottom line.**

Before going  ……..

some words on ECMI (in a sense also global)

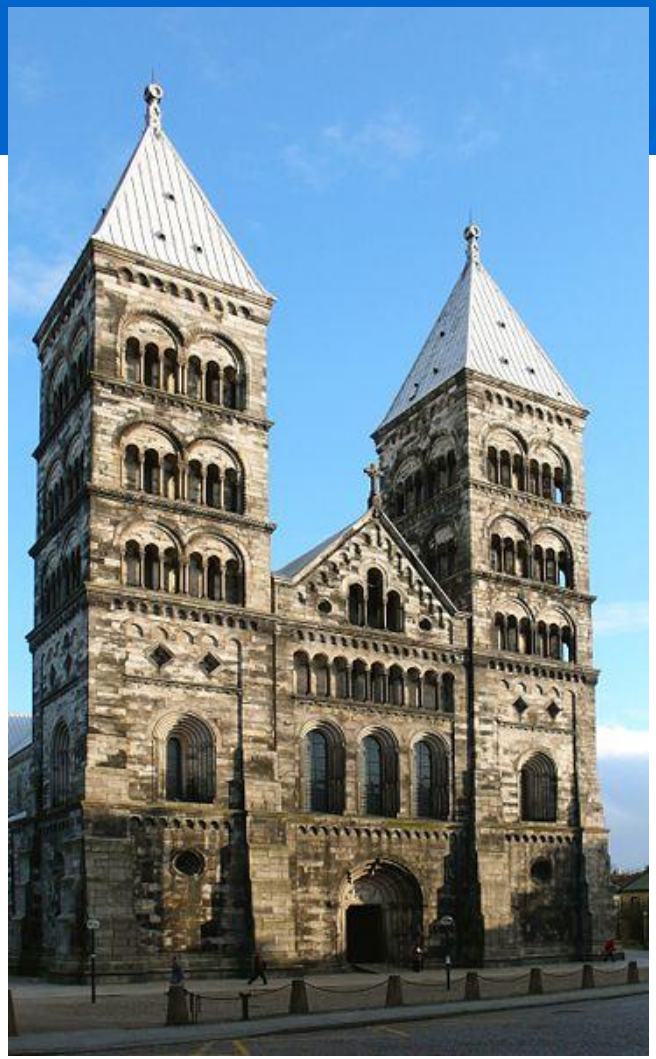
European Consortium for Mathematics in Industry (ECMI)

Major objectives:

- **To promote the use of mathematical models in industry**
- **To educate *Industrial Mathematicians* to meet the growing demand for such experts**
- **To operate on a European scale, and set up contacts on a worldwide scale**

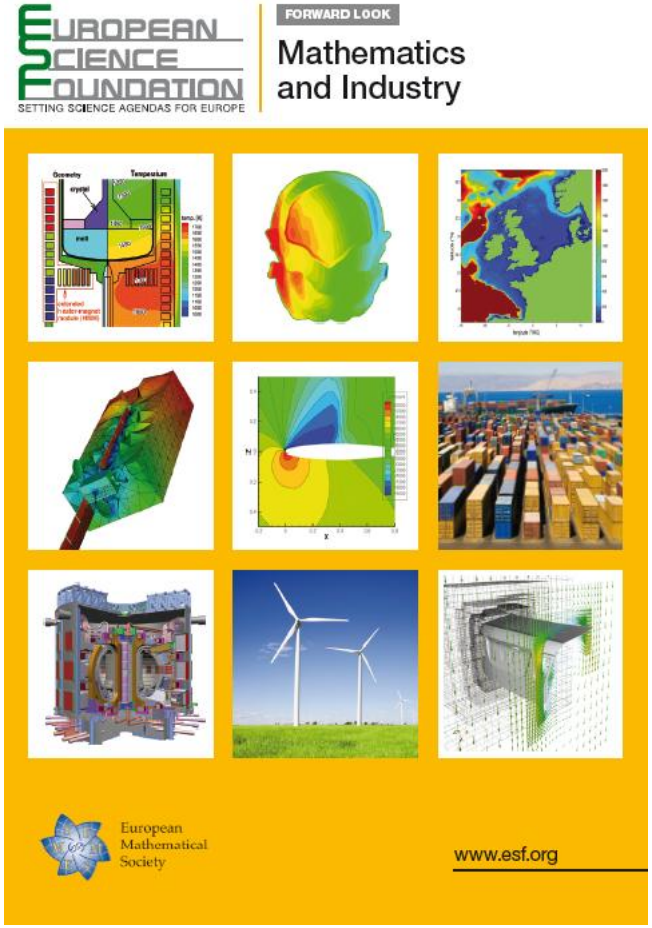
2012: 25 years of ECMI

- **ECMI celebrated its 25th anniversary**
- **The bi-annual conference was held in Lund from July 23-27, 2012, and organized by the new president, Magnus Fontes**



“Mathematics and Industry” Forward Look (2011)

- **ECMI has played an important role in the Forward Look project on “Mathematics and Industry” organized by the European Mathematical Society and the European Science Foundation**



http://www.ceremade.dauphine.fr/FLMI/

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ECMI instruments

- A European curriculum for a master's degree "Mathematics in Industry" has been developed (ECMIMIM project)
  - Important aspect: exchange (3+2 and 4+1)
- The "Studygroups with Industry" (since the 1980's) are one of the most successful instruments to bridge the gap between mathematicians and industry (visit http://www.maths-in-industry.org/)
- "Modeling weeks" are organized on a European scale, and attract on average 80 students from all over Europe
- ECMI has close connections to industry and groups that are active with industry; very useful for European collaborations
  - We observe a tendency that governments move money to the so-called "Innovation" area
  - This is dangerous for "pure" mathematics → loyalty is important

About European Study Groups

- Study Groups on Mathematics with Industry are a very important instrument to connect academia and industry
- Started in Oxford in the 1970's, they have now been adopted on a world-wide scale
  - Within Europe, ECMI is coordinating the study groups
  - In The Netherlands, we have an annual SGI that is organized by a different university each year
  - The Platform for Mathematics in The Netherlands coordinates this effort
  - NWO (basic science funding) and STW (applied science funding) have 5-year commitments and pay appr. 50% of the cost
  - SG with Physics and Informatics!

SGI are one of the best instruments to start contacts with industry

Mathematics and its relationship with industry

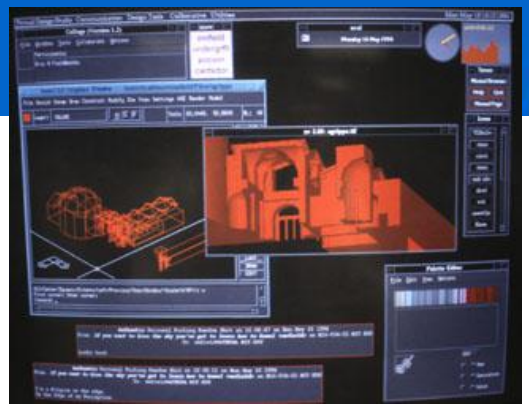
Mathematics as the language for innovation

"Without mathematics it is like walking in the dark"
*(Werner von Siemens to his brother Wilhelm)****

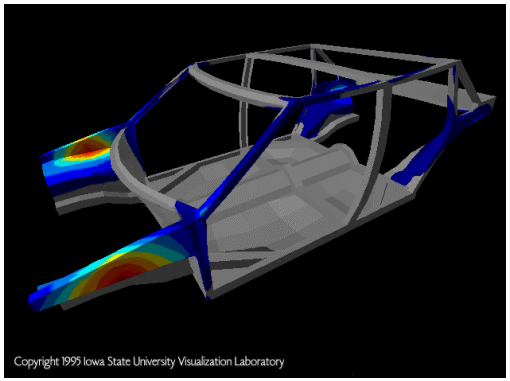
- **The current trend to a global economy and a knowledge society has placed information and innovation technologies, increasingly dependent on scientific research driven by Mathematics, at the forefront.**
- **Mathematics provides the tools, which enable us to understand and reduce the complexity of the mutual interdependencies in economics, and leads the way in predicting, optimizing and controlling the respective systems.**
- **In almost all industries Mathematics opens the way to virtual experiments, the analysis and simulation of multiple scenarios for a given phenomenon and its control and optimization.**

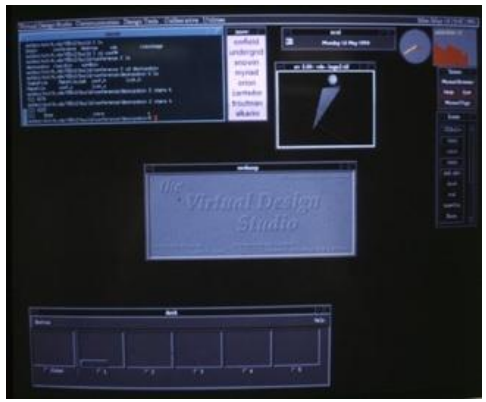
*** More of such statements by current captains of industry in "Mathematics, engine of the economy" (in German)

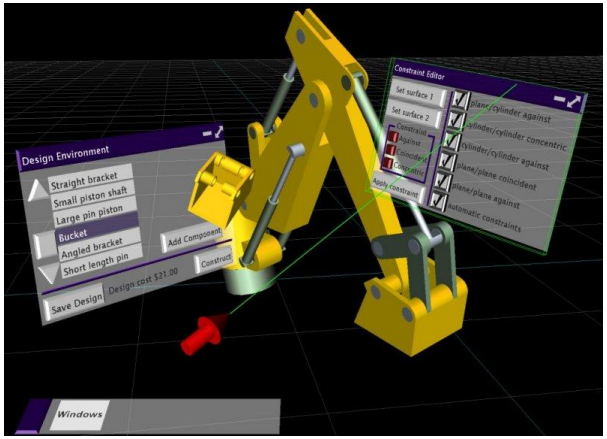
Designing now happens behind a screen



Virtual design environments are everywhere nowadays

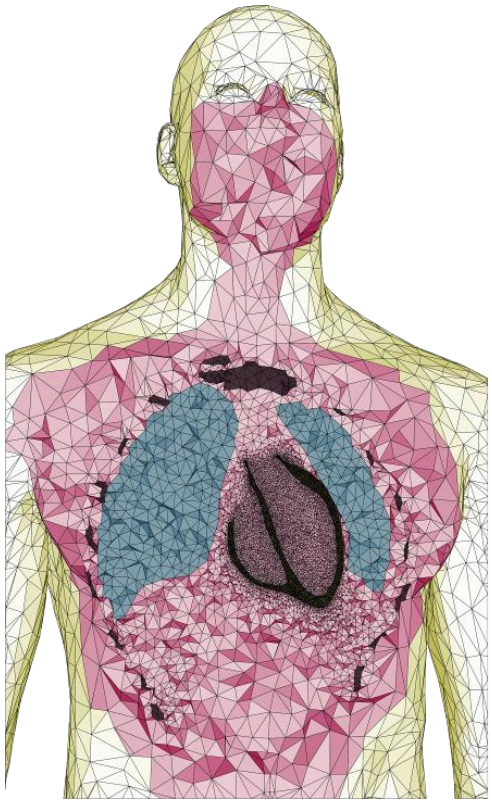




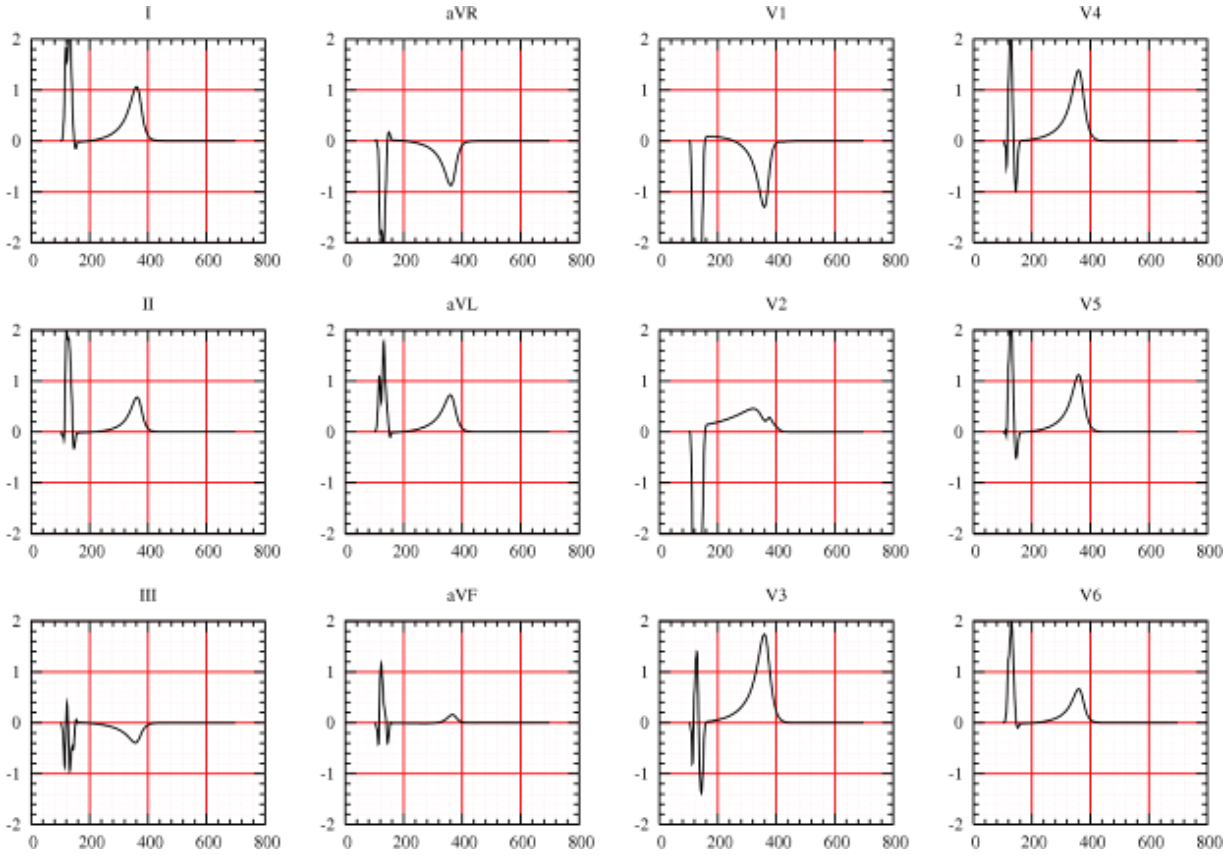


Developing such systems requires huge investments, often by global players

Example: simulation of ECG



The computational domain for the Electrocardiogram



"Healthy" ECG obtained by simulation

Design of aircraft: More Simulation – Less Testing

- A major part of the development costs of an aircraft is incurred by wind-tunnel testing and actual flight tests which are needed in order to obtain aircraft certification.
- In case a problem is detected at this stage of the development it is extremely expensive to modify the design of the aircraft in order to deal with the problem.
- Hence it is of interest to complement the wind tunnel and flight tests by increased use of numerical simulations.
- Numerical wind tunnel by Airbus (2 billion Euro investment!!)
- Virgin (Richard Branson) developed a very unconventional plane using ONLY numerical simulations….and it's flying!

Relevant aerodynamic information for computational flight testing: forces and moments (left), and surface pressure distribution (right)

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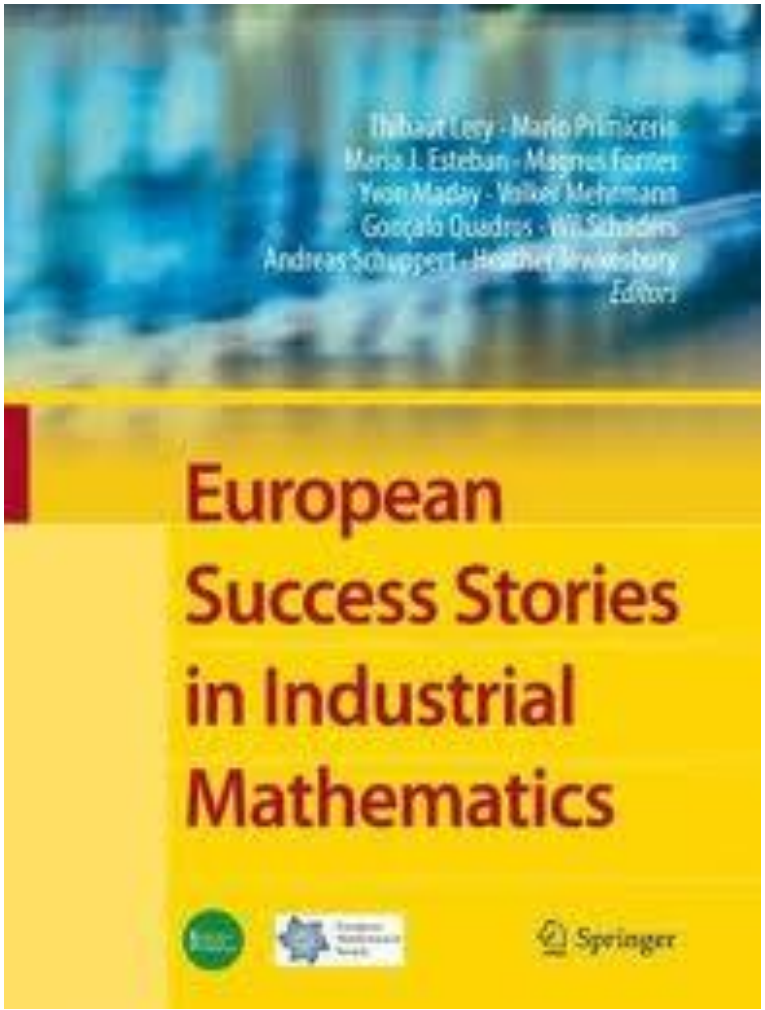
Read more in “Success stories” of the ESF project “Mathematics and Industry”



http://www.ceremade.dauphine.fr/FLMI/

Mathematics as an innovation enabler for industry

- **Google is the apotheosis of how innovation in mathematics and technology can transform a few people into a world-leading services company.**
- **Google evolved from a research project by Larry Page, a PhD student in the Computer Science department at Stanford University.**
- **From this evolved a page ranking algorithm and a search engine based on the rankings, forming a company based on the technology in 1998, in a garage in Silicon Valley.**

"The main challenge is to ensure that there is a good supply of people with mathematical skill sets as they are key to the development of our firm. This expertise is endemic within Google and while the firm can never be sure where the next innovation or product is going to come from, it needs a good supply of university graduates with new ideas and concepts."
Larry Page, Google co-founder

Google sponsors the International Mathematical Olympiad

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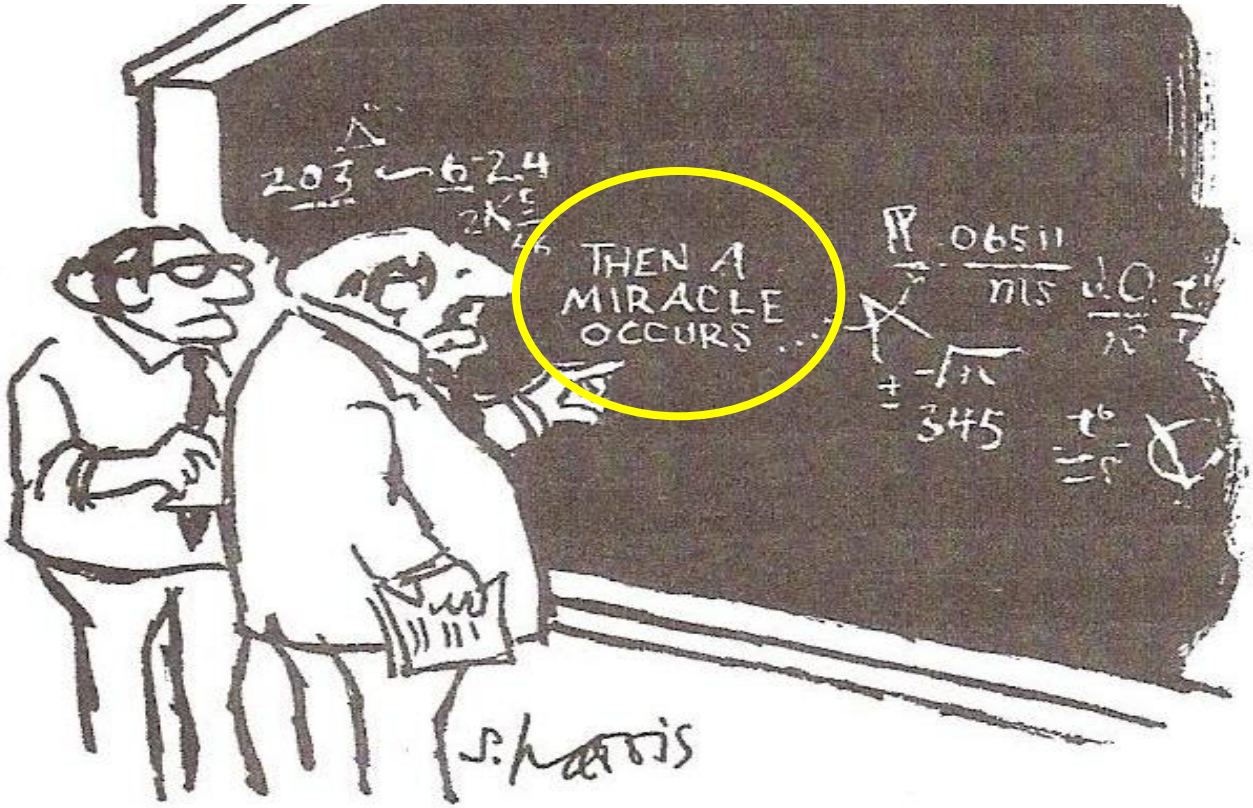
Mathematics in the industrial context

- **The essential program of the applied mathematician when collaborating with industry follows essentially the following paradigm:**
  - **first, identify the problem of concern;**
  - **then, build a quantitative mathematical model, analyse and solve it,**
  - **apply the results,**
  - **and potentially create appropriate mathematical software that can be commercialized.**
- **Typically after the iteration of validating and adapting the model then, when the model is finally accepted, it would be used to improve, optimize or control the process that it describes.**

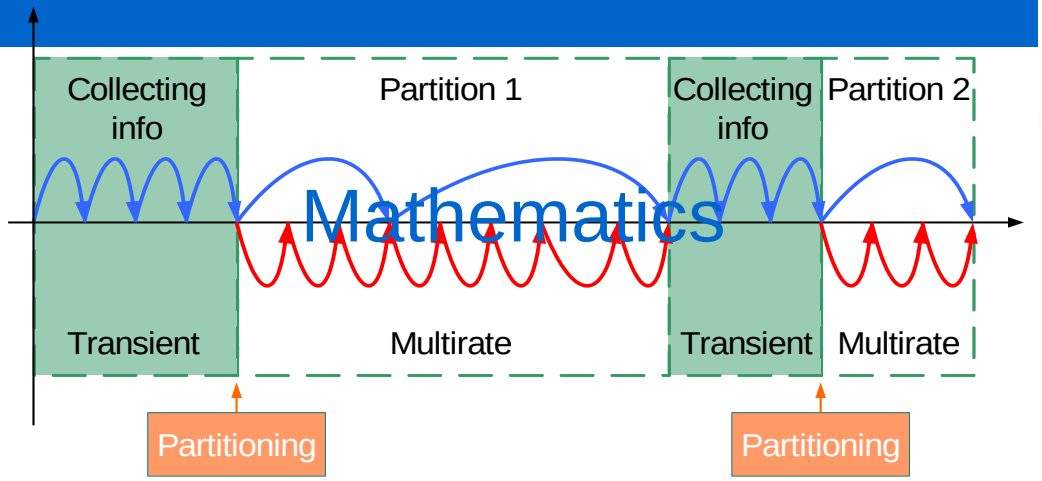
It is evident that, in view of the ever-increasing complexity of real life applications, the ability to effectively use mathematical modelling, simulation, control and optimization will be the foundation for global technological and economic development

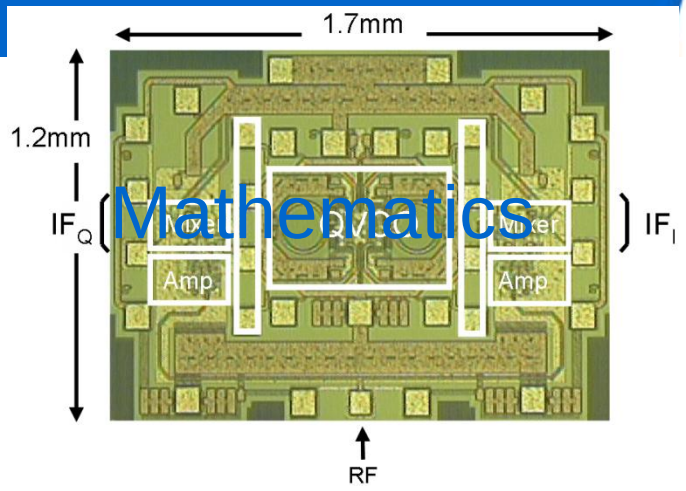
The work of mathematicians in industry is not always transparant

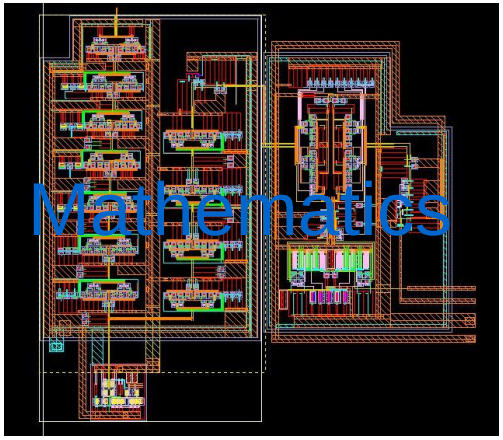


"I think you should be more explicit here in step two."

Mathematics is everywhere, but……







Invisible contribution, visible success

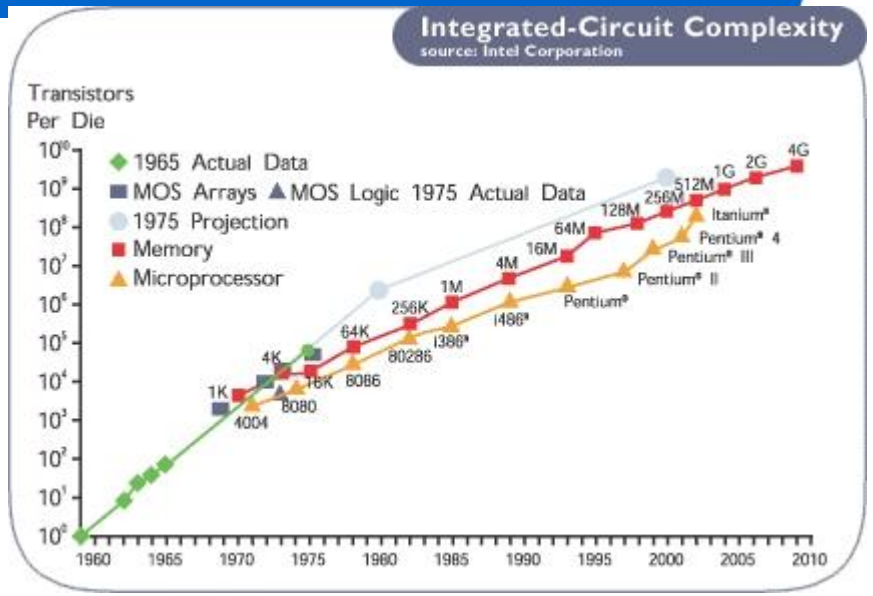
Lack of recognition of mathematics by industry

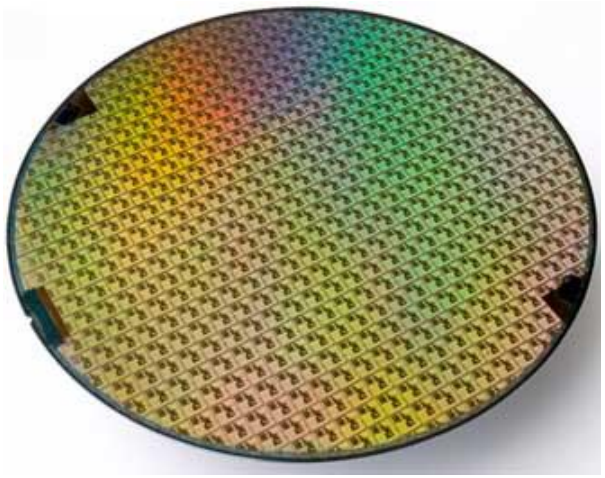
- **Designers use virtual design environments that rely heavily on mathematics, and produce new products that are well recognized by management.**
- **The major effort concerned with the construction of reliable, robust and efficient virtual design environments is, however, not recognized.**
- **As a result, mathematics is not usually considered a key technology in industry.**

Let's look at a stunning example

Law of (Gordon) Moore

The engine behind the chips industry is Moore's law: every 2 years the speed and density of transistors is doubled





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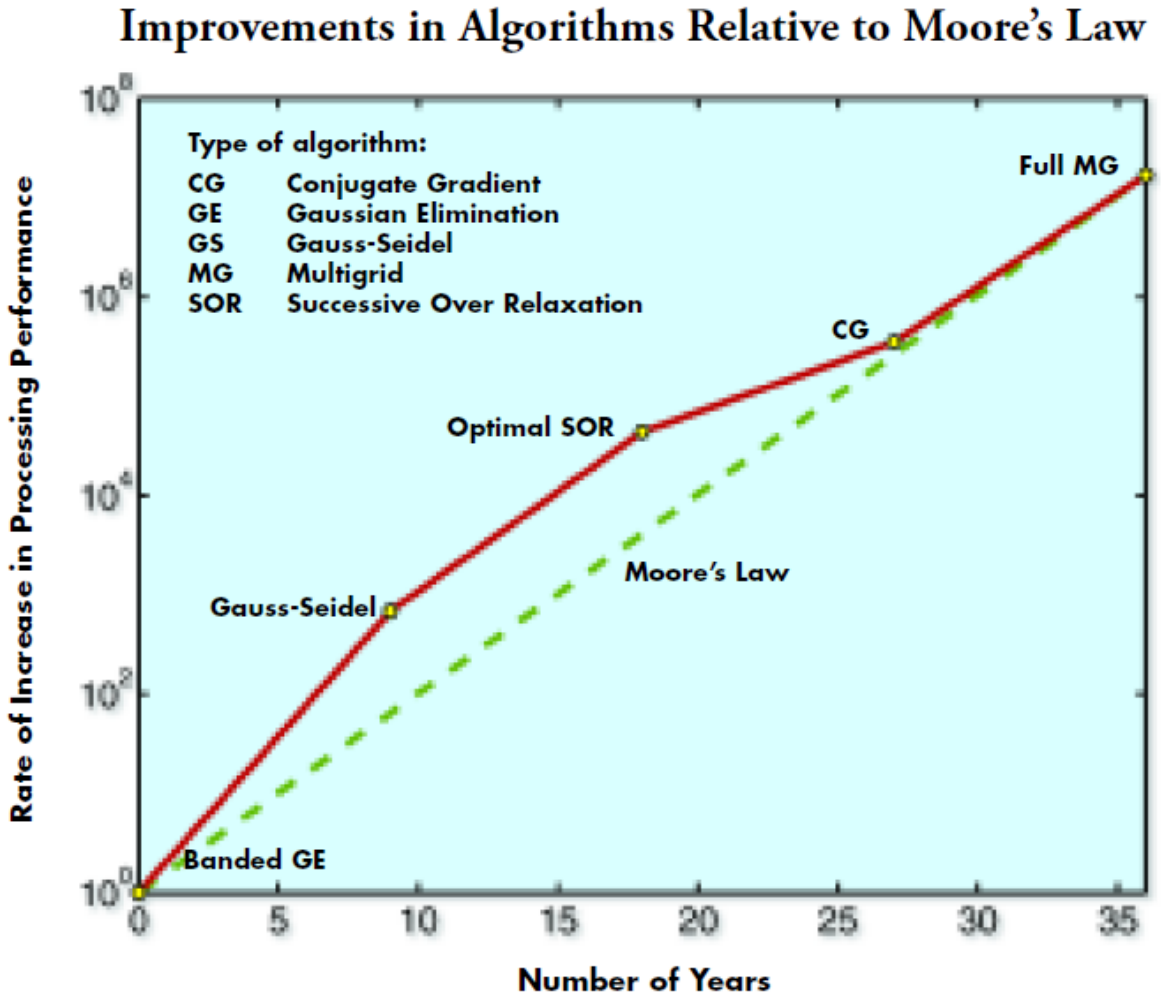
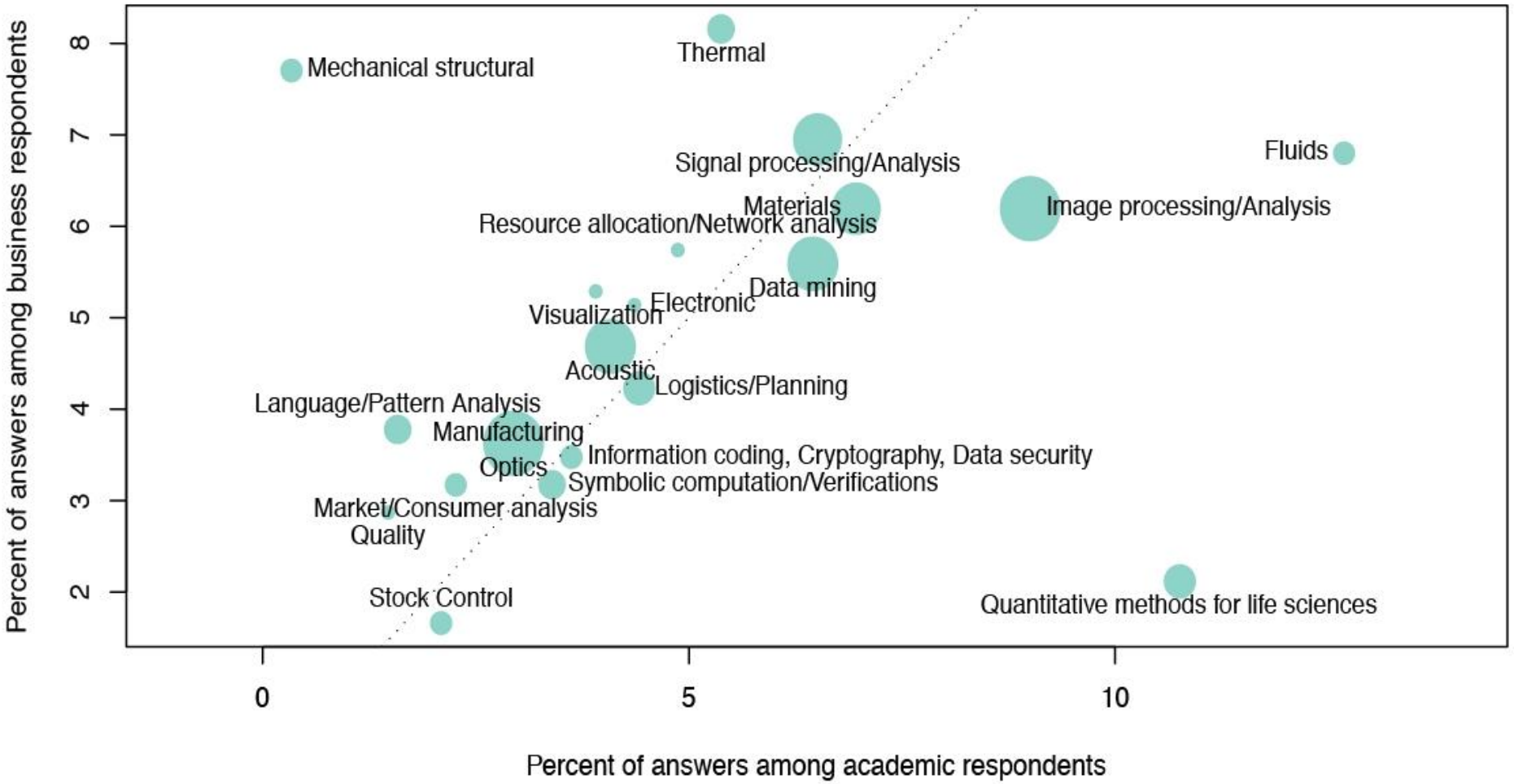
Moore's law also holds for mathematical techniques! (but nobody knows…..)



These effects strengthen each other!

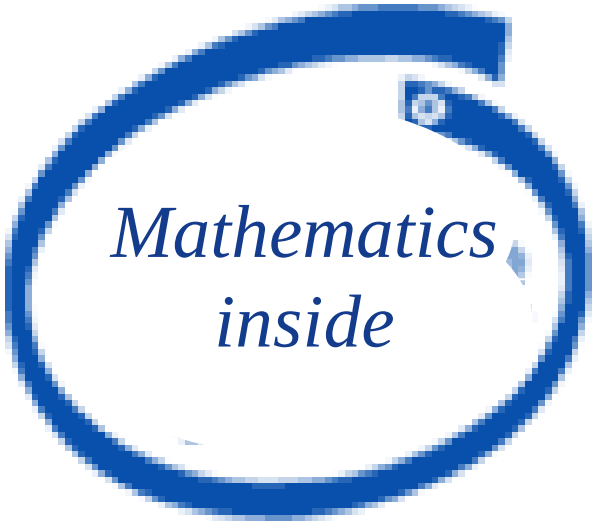
Interaction industry-academia



There exists a fairly good match between the structure of available mathematical competence in academia and the structure of the demand for mathematicians in business

Results and impact of the interaction

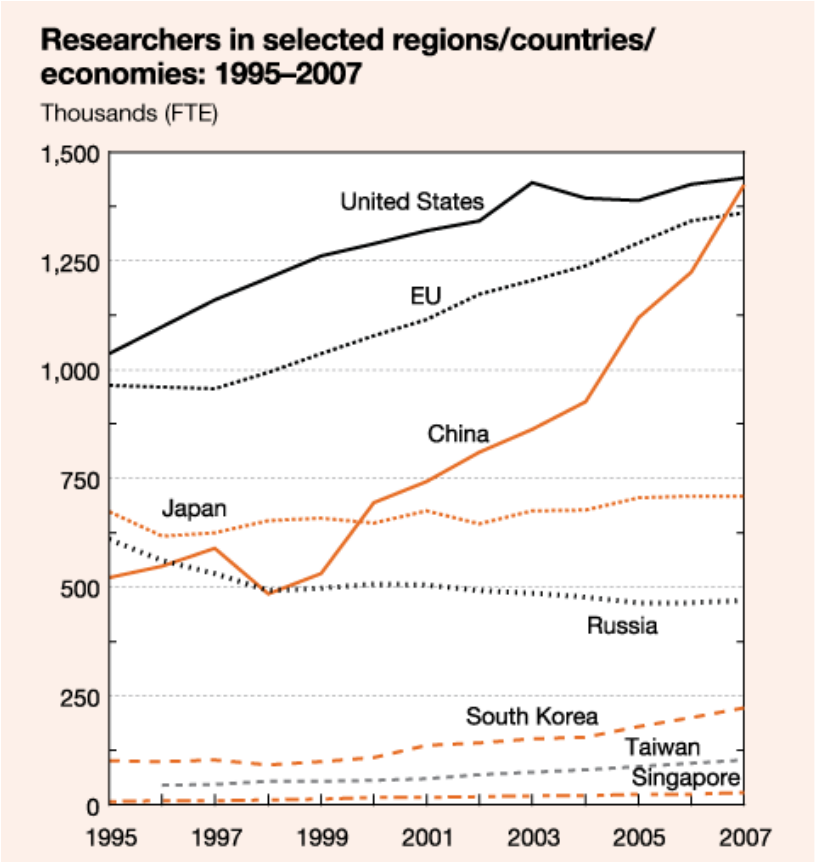
- **The absolutely most important challenge for mathematicians is to further convince industry that they need more and modern mathematics and mathematicians to develop new competitive products and technologies.**
- **A means of convincing more people about the presence of mathematics everywhere could be to put stickers "Math Inside" on products where mathematical techniques have proved the reliability and robustness.**



Challenges and opportunities

Research budgets

- Over the past several decades, numerous countries have gained international standing in mathematics (e.g. Tata Institute of Fundamental Research, Mumbai).
- The major players in science and technology, such as USA and China, have made a substantial increase in the funding of research in many areas of Mathematics over the last decade.



Research budgets

- **It had been understood that a strong national capacity in mathematics is a key to promoting both science and science-based development.**
- **Equally importantly, these countries have concluded that domestic competency in mathematics has an important bearing on the overall quality of a nation's educational base.**
- **India's growing progress in information technology owes much to the mathematical know-how of its knowledge workers.**

The above important developments show that mathematics is a necessary tool for creating innovation (for processes and products) in an interdisciplinary and strategic approach. Hence, innovation and the necessary investment in mathematics are key challenges for industry and funding organisations in order to face competition in the global market.

Opportunities for industrial mathematics

- **The start of the twenty-first century is a particularly exciting time, because there is an ever increasing need for new mathematical concepts and tools to solve problems coming from classical fields as well as from new ones, like Biology, Medicine, data mining, security, communications, and other information technologies.**
- **Industrial mathematicians can make the difference, allowing these fields to make significant strides, many of them of immediate importance to companies and to the society in general.**

"*Mathematics now has the opportunity more than ever before to underpin quantitative understanding of industrial strategy and processes across all sectors of business. Companies that take best advantage of this opportunity will gain a significant competitive advantage: mathematics truly gives industry the edge.*" (UK vision report 2004: "*Mathematics: Giving Industry the Edge")*

Challenges for industrial mathematics

- Industrial mathematics is at the basis of the economical pyramid and is instrumental in the innovation process and in governing complexity. In the context of globalisation, a lack of innovation will make a nation less competitive and will have a dramatic influence on the job market. This will reduce the reaction time to adapt to new challenges.
- A lack of political, societal and financial support will also prevent young researchers from choosing a mathematical career.
- Fragmentation needs to be overcome! Confinement to diverse and independent national priorities is counter-productive.

Challenges for industrial mathematics

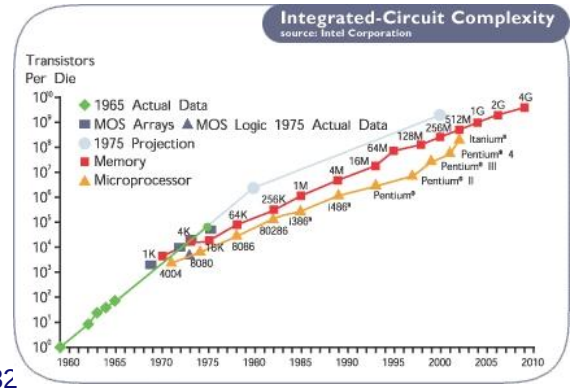
- **Engineering systems and manufacturing processes are becoming increasingly complex; design optimization, time-to-market, and cost effectiveness have become major concerns.**
- **Societal concerns have led to regulatory actions that reflect more stringent requirements for the safety and reliability of products; they demand new methods for validation, verification, and the quantification of uncertainties.**

Mathematicians are the natural candidates for the coordination in industrial problems solving groups, where in addition to the modelling, simulation, control and optimization, the implementation of robust and reliable production software is also necessary. Therefore, there must also be a basic education in modern computer science methods and modern computer architectures.

Opportunities for globalisation

General opportunities (1)

- There is a general increasing awareness about the necessity of using mathematics to improve the competitiveness of the global world economy.
- The arising awareness of the needs of mathematical modelling, illustrated recently for instance in the financial crisis or the global environmental changes, together with the willingness of the mathematicians, makes the timing right to create the necessary synergy.
- Even if complexity is a problem addressed by mathematicians only recently, results already exist and allow to deal with some real life problems in a pertinent way. The latter is amplified by the exponential increase in computing power and numerical algorithms.



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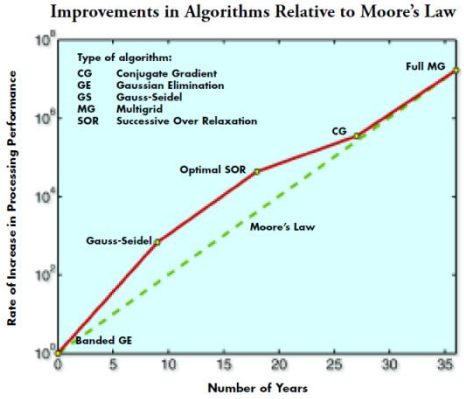

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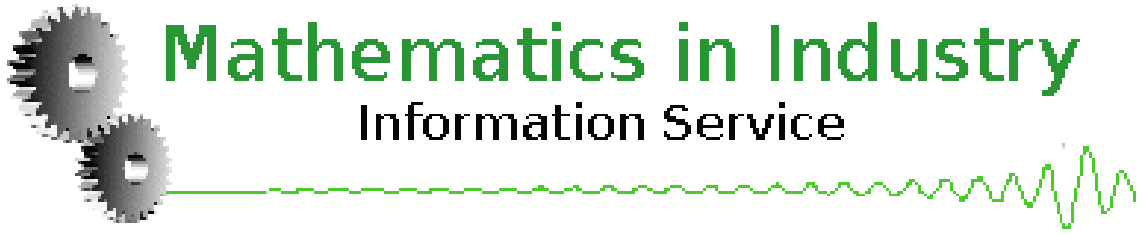
General opportunities (2)

- More and more mathematicians are ready to participate in industrial projects. The potential is there.
- Existing experiences and knowledge can be shared in order to increase the level of industrial collaboration in all countries. Indeed, the existing and reproducible examples of collaboration with industry can and must be spread globally.



http://www.maths-in-industry.org/

General opportunities (3)

- It is timely to start developing common networks and databases of industrial problems, mathematical experts and examples of collaboration. An effort has to be made, but many of the necessary ingredients are already available and will be put in place if our recommendations are followed. At the same time, companies are more and more international.
- The present increase of the amount of data in many fields will require the development of new mathematical and statistical approaches. Moreover, the necessary level of mathematics is nowadays often too sophisticated for a single researcher or research group, so building a strong community is more crucial than ever in order to be able to tackle those problems.

Education for innovation

- Since higher education plays a key role in the transformation to a knowledge based society, many actors are entering the scene: not only professors and students, but also public authorities and social partners.
- All actors have to adjust to this new reality: a reality with a greater number of legitimate actors representing the interests of society, wanting to give their views on and indications to the direction of the development of higher education in the future.
- Research and development must be developed as a whole covering universities, polytechnics, research institutions and industry.

Education for innovation

- **The role of public funding will remain crucial, and indicative of the determination of the public authorities.**
- **One way of developing research resources of universities is promoting the use of private investments from industry together with public funding.**

In order to establish a global mathematical community that is ready to act as a catalyst for innovation in industry and society is the establishment of common points of reference at the Bachelor and Master Degree levels.

Recent initiatives

- **In the USA, a report has been published with the title "The mathematical sciences in 2025"**
- **In the UK, Deloitte published a report "The value of the mathematical sciences"**
  - Important conclusion: around 38% of GVA in the UK can be attributed to the results of research in the mathematical sciences
  - A similar report for physics led to the number 5%
  - The report was discussed in parliament and even in the USA Congress
- **We will conduct a similar survey in The Netherlands**

A new European organisation

- **On November 27 the new network-of-networks EU-MATHS-IN will be inaugurated in Amsterdam**
  - The General Assembly will consist of 1 representative for each European country, representing all of industrial mathematics in that country
  - Objectives: sharing best practices, job offers, information
- **The 2 days preceding this event, EU-MATHS-IN will have a meeting with the president, director and industry representatives of SIAM to discuss common issues and solutions**

Conclusion

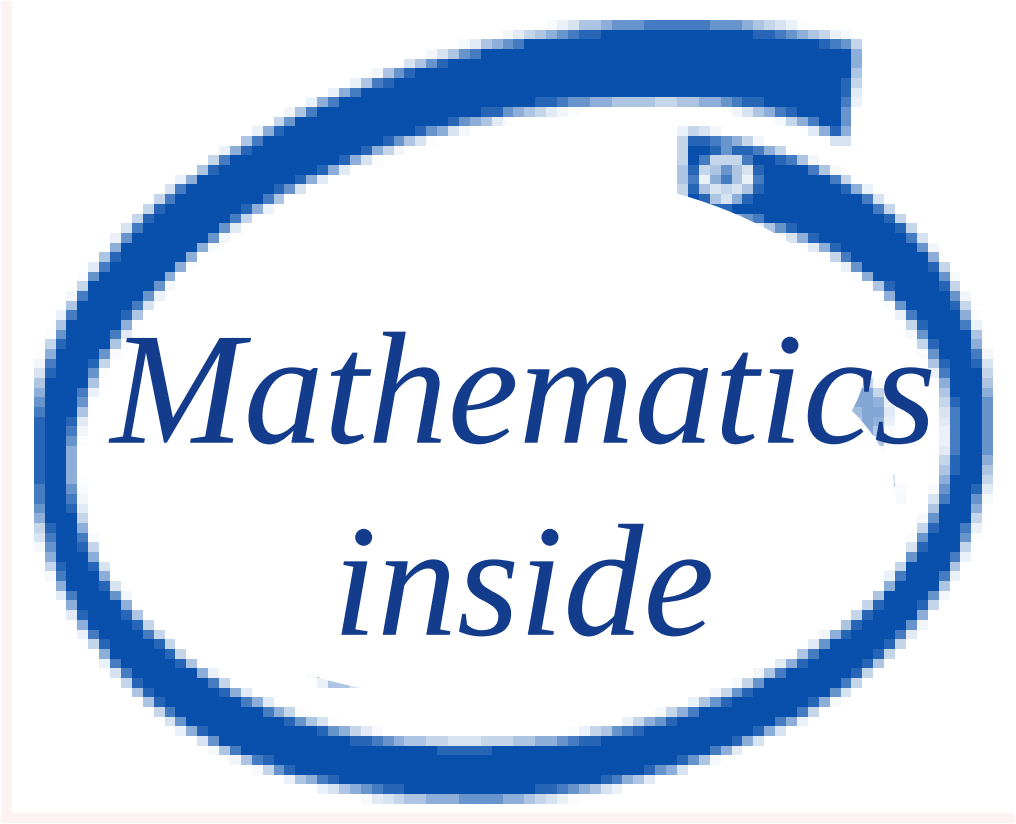
Conclusions

- Knowledge has become the main wealth of nations, companies and people
- Hence investing in research, innovation and education is now the key-leverage for competitiveness and prosperity
- At the heart and foundation of this challenge, mathematics plays a crucial role as it provides a logically coherent framework to industry and a universal language for the analysis, simulation, optimization, and control of industrial processes

Conclusion

- **Smart growth means strengthening knowledge and (industrial) innovation as drivers of our future growth. This requires**
  - **improving the quality of our education, with ample attention for maths**
  - **strengthening our research performance,**
  - **promoting innovation and knowledge transfer.**
- **We should make full use of information and communication technologies and ensure that innovative ideas can be turned into new products and services that create growth, quality jobs and help address global societal and industrial challenges.**
- **At the national level, ensure a sufficient supply of science, mathematics and engineering graduates and to focus school curricula on creativity, innovation, and entrepreneurship.**

And don't forget……



….make the role of mathematics visible!