EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Proposal for a Forward Look on Mathematics and Industry

Presented by

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on behalf of

The Applied Mathematics Committee of the European Mathematical Society

to

The European Science Foundation

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Executive Summary

Objectives

Mathematics provides a universal framework for innovation, which is vital for society and industry. However, the interaction between mathematics and industry is far from optimal. Consequently, a strong inter-connected community and a vision for Europe are needed more than ever.

This Forward Look[1] is aimed at analysing the current state of interaction between mathematics and Industry. Through its analyses and recommendations, it will enable the scientific and industrial communities, together with policy makers, to develop medium to long-term strategies for future research activities and applications. It is expected that it will impact society by strengthening the mathematical knowledge base of a wide spectrum of research-intensive industries. One key goal is thus to define well-adapted and ambitious research and political agendas at national and European levels.

Work-plan

The Forward Look will build on the results of the report on “mathematics and industry” from the Organisation for Economic Co-operation and Development (OECD) by focussing on the specificities of the European context such as its strength, its fragmentation and diversity. It will directly involve Academia and Industry as well as policy-makers. It will systematically include past extensive experiences in the cooperation between academic and industrial researchers together with the political views.

Three working groups will concentrate on specific topics, “Training and career development”, “Academia-Industry interface” and “Opportunities and challenges”. After the initial launch of the Forward Look, thematic foresight activities are planned to take place over one year. The results will be presented in a joint draft report in a consensus conference. Eventually, after incorporating feedback from the relevant communities, the final document will be released in a publicised closing event and disseminated widely.

[1] Initiated by the Centre National de la Recherche Scientifique (CNRS) in France and developed with the support of the Physical and Engineering Sciences (PESC) Unit and the Chief Executive Unit of ESF.

Introduction and Background

Although the role of Mathematical Sciences in Civilization has been of central importance for centuries, the current trend to a *global economy* and a *knowledge society* has situated information and innovation technologies increasingly dependent on scientific research driven by Mathematics. In the present context, the mathematical sciences, including statistics and computing, are considered in their broadest sense. Industry is also interpreted as any activity of economic or social value, including the service industry, regardless of whether it is in the public or private sector. The analysis of their current relationship, including significant trends in mathematical research in academia and industrial challenges that may create opportunities for interactions and partnership between both sides, as well as the formulation of recommendations is the one of the key aims of the present proposal. The Forward Look will benefit from existing studies and activities in Europe and beyond.

Existing studies and activities

- **The OECD report.** Recognising that Mathematics provides the context for communication and discovery in many other disciplines, the Global Science Forum (GSF) of the OECD has issued a report on "Mathematics and Industry", which was published in July 2008. A follow-on activity has recently started at the initiative of the USA. The OECD report contains the basics for a general analysis of the situation worldwide. It also presents a series of policy recommendations (see: www.oecd.org/dataoecd/47/1/41019441.pdf). Some European scientists played a major role in the preparation of the document. They further took part in the preparation of the proposal of this Forward Look and their presence will be instrumental for its success. The Forward Look will build on the results of the OECD report by focussing on the specificities of the European context. Moreover, it will involve not only Academia but also Industry and policy-makers.

- **ICMI-ICIAM.** Still at worldwide dimension, ICMI (International Council for Mathematical Instruction) and ICIAM (International Council for Industrial and Applied Mathematics) appointed a workgroup to prepare a report on training of mathematicians to meet the industrial expectation. European experts belonging to this group are also involved in the present project.

- **European studies and activities**

  - **EMS.** The European Mathematical Society has established a Standing Committee on Applied Mathematics. The "Berlingen declaration" adopted by the Committee includes industrial mathematics as one of the key topics that contribute not only to the development of a modern industry, but also of modern mathematics.

  - **ECMI** –the European Consortium for Mathematics in Industry- is a network of research groups and laboratories, with a regular series of conferences and common activities in research and training. The European School for Industrial Mathematics (ESIM) is an Erasmus Mundus initiative of ECMI partners and ECMI is also currently involved in a Marie Curie Curriculum Development program aiming at setting up a model for a European Master in Industrial Mathematics. Its experience will be essential for the implementation of the Forward Look.

  - **Trans-national activities.** Several European initiatives have been taken in the past. See e.g. A Roadmap for Mathematics in European Industry (MACSI-Net Mathematics, Computing and Simulation for Industry. A European funded network of Excellence (2000-2004)) http://www.macsinet.org/newsletter.htm#MARCH2004. At bilateral and multi-lateral levels, there are several ongoing activities whose experience will contribute to the Forward Look.

  - **National activities.** In many European countries, there exist research centres whose mission is the modelling simulation and optimization of industrial processes. They utilise a large spectrum of approaches and obtain important results in many branches of industry, e.g. aerospace and defence, automotive, chemical, electronics, energy, medicine, textile, IT, telecommunications etc. Many European mathematical societies have specific programs in industrial mathematics (working groups with industry, modelling weeks, stages, internships...). Some national institutions have produced or are currently producing fact-sheets and road maps, which will be instrumental to our work.

- **Other studies.** Several committees, mainly in the United States, investigated the state and the role of Mathematics and its relation to Science and Technology. Most of the reports were produced prior to 2000. Most of them are listed in the OECD report.

Analysis of the European landscape

Strengths:

- Mathematics is the language of innovation, which is vital for society and industry.
- Counted together, European mathematics is by far the World leading school.
- In many European universities and research centres, mathematicians are frequently organised in communities at national level. In collaboration with Industry, they have developed a large expertise at the forefront of research involving most fields of mathematics.
- There exist scattered networks of centres, exchanging students in common training programs in industrial mathematics, that have a long tradition and experience, forming a scientific community in the making. The diversity of approaches and cultural differences is a key factor for cross-fertilization.
- Communication channels between Industry and Academia are already established in many countries. In some cases, mathematicians occupy important positions in industrial R&D, especially within large companies that have in-house research departments.

Weaknesses:

- Despite the work and efforts of the European mathematical organizations, the communities are still not sufficiently inter-connected and remain fragmented.
- Among European countries large differences remain in the tradition of establishing links between research and industry. Companies have in many cases insufficient trust in academic research and particularly in mathematics. This is particularly true for SMEs, for which innovation should be the main concern, in order to face worldwide competition.
- Regardless of the vital societal and scientific role of industrial mathematics, its recognition is not high in the European and national political agendas. In addition, the scientific community has often underestimated the value of applied and application driven research. This has led to a difficulty in its evaluation and recognition.
- Academic careers in the field of industrial mathematics have somehow suffered from a lack of recognition and of a clear identity. Similarly, large companies often have an in-house research department but no career development for mathematicians.
- Finally, in the mathematical community at large, there has been no clear sign of integration of mathematicians working in companies.

Opportunities:

- Innovation is the main challenge for European industry to face competition in the global market and is crucial for the survival of industry in Europe. Mathematics is a necessary tool for leading innovation (for processes and products) in an interdisciplinary approach.
- The European industrial landscape is characterised by the strong presence of SMEs. They could benefit enormously from outsourcing their research. The development of stronger interactions and networking in the community would be an opportunity for both Industry and Academia.
- 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 than ever crucial to tackle those problems.
- 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.

Threats:

- In the context of globalisation, a lack of innovation will make Europe less competitive and will have a dramatic influence on the job market. Industrial mathematics is at the basis of the economical pyramid and is instrumental in the innovation process and in governing complexity. This may also increase the length of reaction time to adapt to new challenges
- A lack of political, societal and financial supports will also prevent young researchers from choosing a mathematical career. As a consequence, Europe may not keep its leading role in mathematics.
- There is a risk to increase isolation of researchers and consequently a reduction of collaborative expertise. This may also lead to confining cooperation of mathematics and industry to large companies.
- Confinement to diverse and independent national priorities would be counter-productive without a strategy at European level.

Added value of a Forward Look in this area

Mathematics and Industry need a Foresight study in order to develop a vision for Europe. The main motivations for this activity come from:

- Its **dimension** at European scale: initiatives at national level risk being fragmented and non-strategic; on the other hand, an initiative at world level risks being less focussed and difficult to implement.
- **The right timing** as Europe is engaged in its ambition to become the world's most dynamic ***knowledge-based economy.***
- The **inclusiveness** through the involvement of all the main stakeholders in the process: i.e. industry (large companies and Small and Medium Size (SME) companies), research-intensive and consulting companies, researchers and scientific societies, policy makers and media experts.
- **Its impact on European strategy** through the dissemination of its outputs to key stake-holders, e.g. European Commission, National Governments, Funding organisations, Labour and Industry associations.

We are convinced that mathematics offers unique power and flexibility for innovation across a broad spectrum of applications by providing a unifying methodology for studying complex phenomena and processes and stimulating the interdisciplinary approach that is demanded by the complexity of the world that we need to understand and control. In particular, more than ever before, mathematics has the opportunity to underpin quantitative understanding of industrial strategy across all sectors of business. It is a necessary instrument for innovation, and thus for achieving significant competitive advantages: ***mathematics truly gives industry the edge.*** We are convinced that the Forward Look will be the catalyst in this endeavour.

Purpose of the Forward Look

Purpose

The goal of the Forward Look is to explore ways of stimulating and/or intensifying the collaboration between Mathematics and Industry. It will enable Europe's scientific community, in interaction with policy makers, to develop medium to long-term views and analyses of future research activities with the aim of defining research agendas at national and European level. The present project will identify common issues, questions, and "good practices" between Mathematics and Industry in order to envisage strategies for a stronger interaction of mathematicians with large and medium size companies aimed at technological advancement.

Scientific scope

The collaboration among different centres will have a direct impact on the quality and level of the mathematical research at large in Europe. Challenges arising from industrial problems will demand the implementation of new and groundbreaking methods, at the different levels of modelling, analysis of the mathematical problem, scientific computing, optimization, and simulation. From the point of view of training of students, a better understanding of the needs of application and of the importance of industrial problems for the development of their discipline will induce a renewed didactics (both in its forms and in its contents), in all branches of mathematics.

Industrial scope

Mathematics is a key and enabling technology for industry, as it provides a logically coherent framework and a universal language for the analysis, optimization, and control of industrial processes, even if its contributions are, in most cases, invisible in the industrial products. For large companies with in-house R&D activities, the Forward Look will outline the role that mathematics could play within the research teams. It can give a competitive advantage to industry by suggesting innovative interdisciplinary approaches, by simulating virtual production scenarios. It could also improve the training of the mathematicians who will work in industry, and help by identifying academic networks of laboratories and their potential role for new emerging problems. For SMEs outsourcing expertise, it will clarify the need for innovation and usage of mathematics and show the benefits of the cooperation with academic research.

Societal scope

Detailed information on the involvement of mathematics and mathematicians in industrial innovation and development in the various European countries will be provided in the fact-sheets that are one of the deliverables of the project. This can be a fundamental instrument for the decision makers at European level.

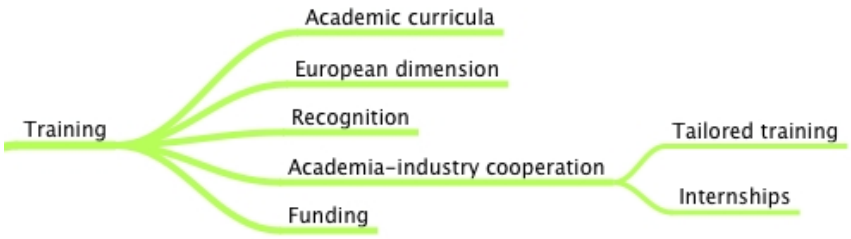
Working groups

The activity of the Forward Look will be structured in three working groups dedicated to “Training and career development”, “Academia-Industry interface” and “Opportunities and challenges”.

Working Group 1a: Training

Coordinator: Magnus Fontes (member of the ECMI Council and chairman of its Educational Committee)

WG1a Key items



WG1a Key questions

- **Academic curricula**. What are the specific university curricula preparing mathematicians to tackle industrial problems? - Survey of differences and similarities across Europe.
- **European dimension.** How to improve mobility at European level? Standardisation and compatibility: should there be European degrees?
- **Recognition.** What should be the format of the curriculum for a full recognition of the expertise?
- **Academia-Industry cooperation**. Does research in Industry contribute to development of curricula? Should the training be adapted to and influenced by industrial needs, and how?
- **Tailored training.** What is the modus operandi of the teaching, including the possibility/opportunity to offer companies intensive courses of permanent training etc?
- **Internships.** How to evaluate and integrate training activities in an industrial context into the curriculum?
- **Funding**. Which forms can Industry funding of academic research and training take?

Working Group 1b: Job and Careers

Coordinator: Magnus Fontes (member of the ECMI Council and chairman of its Educational Committee)

WG1b Key items

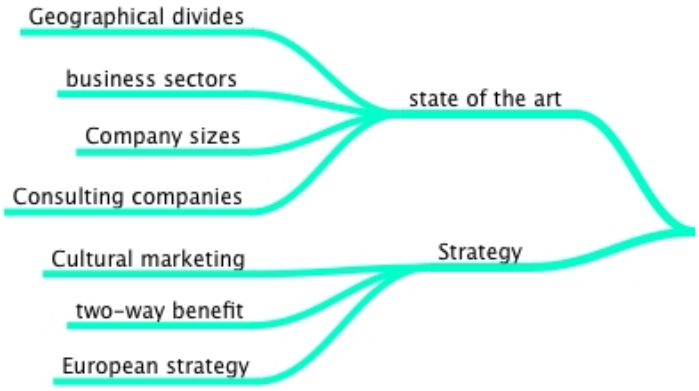
WG1b Key questions

- **Roles of mathematicians.** Which roles do mathematicians play in the industrial system? What are the specific mathematical skills that are relevant to industry? Are mathematicians employed according to their specific knowledge and/or their skill?
- **Academic perspective.** What is the "identi-kit" of European mathematicians working in industry? Which are the skills they are required to possess in their mathematical tool-boxes? Which kind of permanent training might be useful for them and for their employers?
- **Industrial perspective.** How do European industries recruit mathematicians? Is there a specific professional profile required or is recruitment just aimed at appointing a scientifically qualified person whose real training will be made directly within the company? Do industries consider that a Ph.D. degree in Applied Mathematics is an important criterion in the curriculum of the persons who apply for a job? How to open their career development?
- **Job-market.** How should we operate to stimulate a truly European Job-market for industrial mathematicians?

Working Group 2: Academia-Industry Interface

Coordinator: Volker Mehrmann (Vice-chair of the EMS applied mathematics committee, Chair of Matheon)

WG2 Key items



WG2 Key questions

- **State-of-the-art.** What is the state of the art of interaction between University and Companies in Europe as far as mathematics is concerned? Survey for the various business sectors**.**
- **Business sectors.** Which are the business sectors and technological areas in which cooperation is more developed? If there are large differences between different sectors, how can this be changed?
- **Company sizes.** Which are the differences between large companies and SMEs, e.g. in-house expertise?
- **Consulting companies.** What are their role and importance?
- **Two-way benefit.** How to foster a permanent beneficial two-way exchange between Industry and Academia?
- **Geographical divides.** What is the situation with respect to geographical differences?
- **Cultural marketing.** How to increase the visibility of mathematics as a driving force for industrial innovation in Europe? How to measure its impact? How to improve confidence and trust building?
- **European strategy**. What should be done to meet European industrial strategy? What are the gaps and structural changes and how to overcome them?

Working Group 3: Opportunities and Challenges

Coordinator: Yvon Maday (President of the scientific council of SMAI and manager of the industrial relations of the Foundation *Sciences Mathématiques de Paris*)

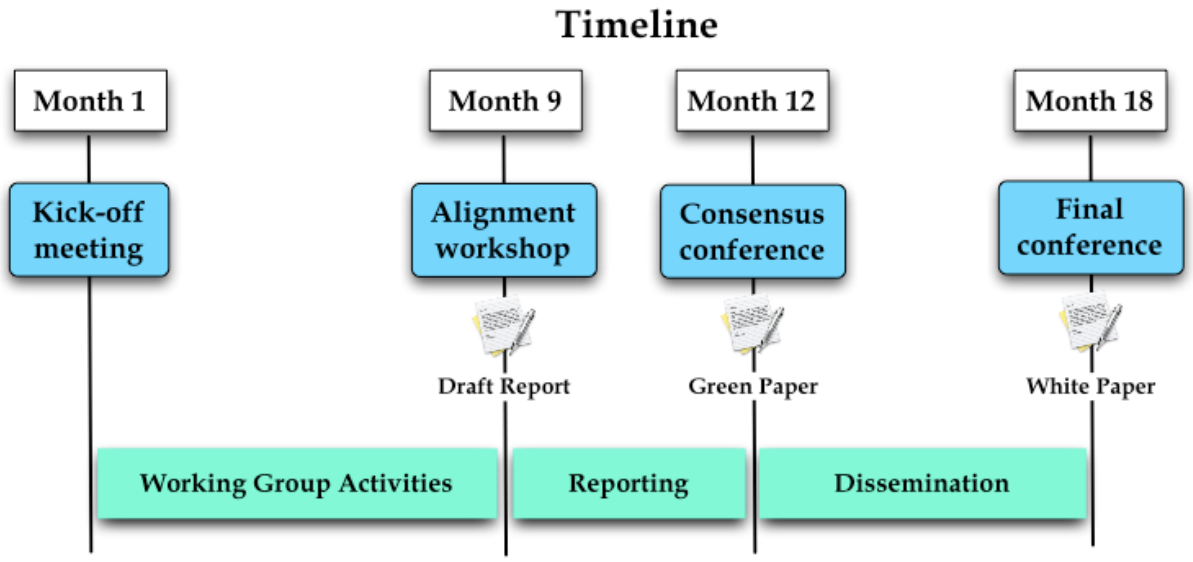
WG3 Key items

WG3 Key questions

- **Success stories.** Are there success stories of cooperation between research groups in mathematics and companies that can be viewed as benchmarks for the community? How could this cooperation benefit from a European framework?
- **Boundaries of mathematics.** Up to what limits, should mathematicians be involved in industrial projects? Should they propose a "stand-alone" consultancy or should they present themselves as potential team leaders for research groups?
- **Challenges for SMEs.** How to integrate confidentiality issues in problems of common interest?
- **Diversity as a resource.** Which are the main differences among the methods of interaction used in different countries? How could this diversity become an opportunity for Europe and not reduce just to fragmentation?
- **Building a Community.** How to integrate in the community the mathematicians working in Industry? What is preventing them from joining? How to evaluate and acknowledge their contribution? What are the potential instruments or institutional bodies that would catalyse such a community? Could an "alliance" of European mathematical research laboratories be instrumental to support European industry?
- **Strategic opportunities.** What are the targets of strategic importance for Mathematics and Industry, and the tools to reach them? Virtual hubs, virtual and/or centralised institute, Expert Committees, a virtual Research Infrastructure. How to synchronise activities taking into account the political agendas?

Schedule of activities

Date	Task	Deliverables
Month 1[2]	Starting the activities	Launch event
Month 2-7	Gathering of data for the preparation of working papers;	Workshops and reports
Month 8	Meetings of the working groups, involving stakeholders	Workshops and reports
Month 9	Merging the data	Alignment workshop
Month 12	Consensus conference: production and presentation of the draft of the final report	Conference. Green paper "Mathematics and Industry in Europe"
Month 13-18	Dissemination actions and feedback from stakeholders	Final report: white paper including perspectives; recommendations and scenarios.
Month 18	Final Conference and dissemination	Report on the dissemination actions. Final conference



[2] Following the Science Advisory Board meeting in mid-March 2009, the Forward Look activities could start around April 2009

Contributors to the Forward Look

Contributors from Academia

- **Members of the Applied Mathematics Committee of the European Mathematical Society** (The list can be found at www.ceremade.dauphine.fr/EMS-frames/EMS-frames-index.html)
- **Members of the European Consortium for Mathematics in Industry Council** (The list can be found at www.ecmi-indmath.org) and of its **Educational Committee** (The list can be found at www.ecmi-indmath.org/edu/educom.php)
- **Representatives of research institutions** where the practice of contracts is an established tradition will be invited (cf. the list on pages 22-23 **of the OECD report** with the necessary additions - see the full document at www.oecd.org/dataoecd/47/1/41019441.pdf
- The European members of the OECD Global Science Forum. The list can be found in the OECD report mentioned above on page 29 to 35.
- Researchers from non-European countries.

Contributors from Industry

- Representatives of the large multinational research-intensive companies having important presence in Europe, both from the strategic level and the R&D sectors.
- Experts from specific areas (in industry and/or services) with career experience in small and medium enterprises.
- Representatives of industry and services associations.

Relevant International Organisations

- The European Commission.
- The European Research Council.
- The OECD.
- The Member Organisations of the European Science Foundation.

Participants in the preparatory workshops

Frankfurt meeting of the EMS Applied Mathematics Committee (24 Sept. 08)

Participants:

Dr. Maria J. Esteban (CNRS), Prof. Helge Holden (representative of the Executive Committee of EMS), Prof. Sam Howison, Prof. Rolf Jeltsch, Prof. Steffen Lauritzen, Prof. Anders Lindquist, Dr. Yvon Maday, Prof. Piero Marcati, Prof. Luisa Mascarenhas, Prof. Volker Mehrmann, Prof. Lukasz Stetter, Prof. Helmut Neunzert, Prof. Mario Primicerio.

Pisa ESF scoping workshop (20-21 Dec. 08)

Participants: Dr. Maria J. Esteban (France), Prof. Magnus Fontes (Sweden), Prof. Luca Formaggia (Italy), Prof. Michael Günther (Germany), Prof. Mats Gyllenberg (Finland), Prof. Matti Heiliö (Finland), Prof. Helge Holden (Norway), Prof. Willi Jaeger (Germany), Dr. Robert Leese (UK), Prof. Manuel de Leon (Spain), Prof. Anders Lindquist (Sweden), Dr. Y. Maday (France), Prof. Mario Primicerio (Italy), Prof. Jose-Francisco Rodrigues (Portugal), Prof. Wil Schilders (The Netherlands).

Observer: Prof. Jean-Pierre Bourguignon, member of the Scientific Advisory Board of ESF.

Facilitators: Chantal Durant (PESC Unit) and Dr. Thibaut Lery (Chief Executive Unit, ESF).

Paris ESF drafting workshop (26-27 Jan. 09)

Participants: Dr. Maria J. Esteban, Prof. Magnus Fontes, Dr. Yvon Maday, Prof. Mario Primicerio.

Observers:

Prof. Jean-Pierre Bourguignon, member of the Scientific Advisory Board of the ESF.

Dr. François Blanchard and Dr. Jean-Marc Gambaudo science officer attached to the Director General of CNRS for a new institute of mathematics, former deputy director of the mathematics scientific department in CNRS.

Prof. Mats Gyllenberg (Chair of the PESC Standing Committee of ESF).

Facilitator:

Dr. Thibaut Lery (Chief Executive Unit, ESF)