



# European Service Network of Mathematics for Industry and Innovation

***Towards a European Technology Platform for  
Mathematical Modelling, Simulation and  
Optimisation (ETP4MSO)***

**Finnish Mathematical Days  
Joensuu, January 4-5, 2018**



**....OF MATHEMATICAL BIOLOGY**

**& FOR INDUSTRIAL MATHEMATICS**

# Mathematics for industry is gaining momentum

- The “I” in **ECMI**, **ICIAM** and **SIAM**
- Also the “I” in the COST network **MI-NET** (<https://mi-network.org/>)
  - European Studygroups of mathematics with industry organized in many countries
- Still misunderstandings about industrial and applied mathematics: “applied mathematics is just about applying existing mathematics”
- Absolutely not correct:



# “New mathematics inspired by industrial challenges”

- The chapters contained in this book clearly show that industrial challenges do lead to the development of new mathematical methods, or even completely new fields of mathematics, needed to address these challenges.
- Some of the topics:
  - Methods for solving indefinite linear systems
  - Topological data analysis
  - Model order reduction
  - Random preconditioners
  - LQR/LQG controllers
  - Differential-algebraic equations
- Expected summer 2018



# EMS and ECMI created EU-MATHS-IN end of 2013



**Umbrella for all  
industrial  
mathematics  
activities in Europe**

# EU-MATHS-IN: a unique network

- EU-MATHS-IN is a network of national networks that represent the entire community in their respective countries with respect to mathematics for industry – started November 2013
- 17 national networks currently on board (December 2017):
  - IMNA (Austria)
  - BE-MATHS-IN (Belgium)
  - CNMI (Czech Republic)
  - **FI-MATHS-IN (Finland)**
  - AMIES (France)
  - KoMSO (Germany)
  - HSNMII (Hungary)
  - MACSI (Ireland)
  - Sportello (Italy)
  - NNMII (Norway)
  - PL-MATHS-IN (Poland)
  - PT-MATHS-IN (Portugal)
  - RO-MATHS-IN (Romania)
  - math-in (Spain)
  - EU-MATHS-IN.se (Sweden)
  - PWN (The Netherlands)
  - UK KTN (UK)
- *BGSIAM (Bulgaria) negotiating*



Mission: EU-MATHS-IN aims to leverage the impact of mathematics on innovations in key technologies by enhanced communication and information exchange between and among the involved stakeholders on a European level.

Contact us at  
[www.eu-maths-in.eu](http://www.eu-maths-in.eu)

# HISTORY

# Several studies on 'Mathematics in Industry'

- [PITAC Report 2005 Computational Science](#) : Ensuring America's Competitiveness
- [NSF report](#) : "Revolutionizing Engineering Science through Simulation", 2006.
- [OECD - Global Science Forum](#) : Report on "Mathematics in Industry", 2008, 2009
- SIAM reports on Mathematics for Industry








# Final reports of Forward Look

**EUROPEAN SCIENCE FOUNDATION**  
SETTING SCIENCE AGENDAS FOR EUROPE




**FORWARD LOOK**  
**Mathematics and Industry**

 European Mathematical Society

[www.esf.org](http://www.esf.org)

Thibaut Lery · Mario Primicerio  
Maria J. Esteban · Magnus Fontes  
Yvon Maday · Volker Mehrmann  
Gonçalo Quadros · Wil Schilders  
Andreas Schuppert · Heather Tewkesbury  
*Editors*

**European Success Stories in Industrial Mathematics**

   Springer

**Recommendation 2: In order to overcome geographical and scientific fragmentation, academic institutions and industry must share and disseminate best practises across Europe and disciplines via networks and digital means.**

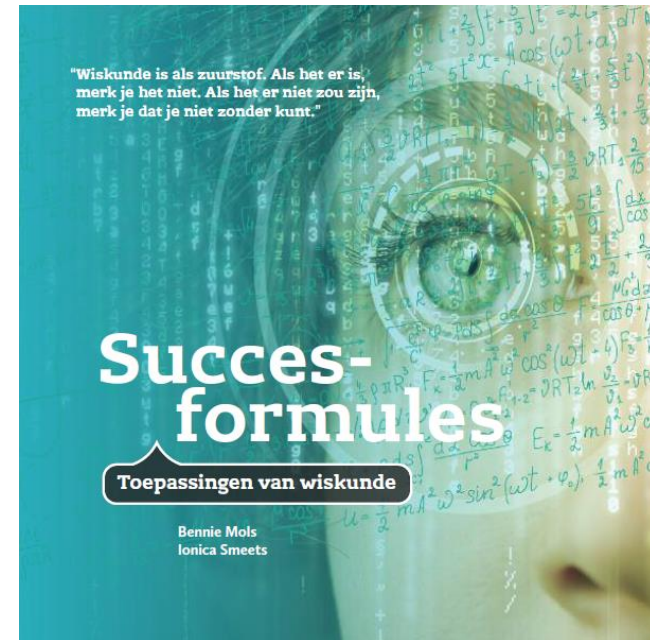
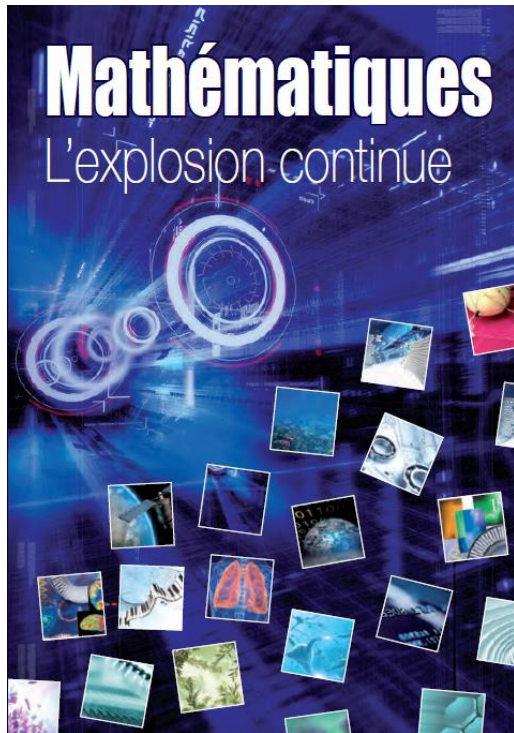
Roadmap implementation:

- Researchers in academia and industry must adapt their mentalities to the different mathematical and scientific domains they interact with, and disseminate best practises.
- The mathematical community in collaboration with industry should create a journal devoted to industrial mathematics and contribute to a European Digital Mathematics Library.
- Academic institutions and industry must facilitate the employment mobility between academia and companies.
- The mathematics community and industry should work together on real opportunities in application-themed competitions.



**EU-MATHS-IN**

# Many experiences to be exchanged



**Books with success stories**

*“Mathematics is like oxygen. If it is there, you do not notice it. If it would not be there, you will immediately notice.”*

# Many experiences to be exchanged

- AMIES has set up a very successful job portal for maths jobs in industry (now in EU-MATHS-IN)



PRIX DE THESE  
Maths  
Entreprises  
2014

AGENCE POUR LES MATHÉMATIQUES EN INTERACTION AVEC L'ENTREPRISE ET LA SOCIÉTÉ

- KoMSO has performed a very extensive national strategy discussion for Mathematics - Industry
- KoMSO organises “Challenge workshops”

## KoMSO



# Reports on economic benefits



## Measuring the Economic Benefits of Mathematical Sciences Research in the UK

- Mathematical sciences research responsible for 25-30 percent of GVA (direct, indirect, induced)
- Labour market will go through transition in next 30 years: service jobs taken over by computers, sound basis in mathematics will be a requirement for the new types of job

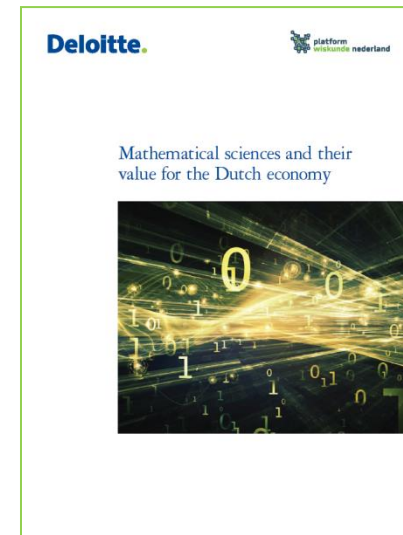
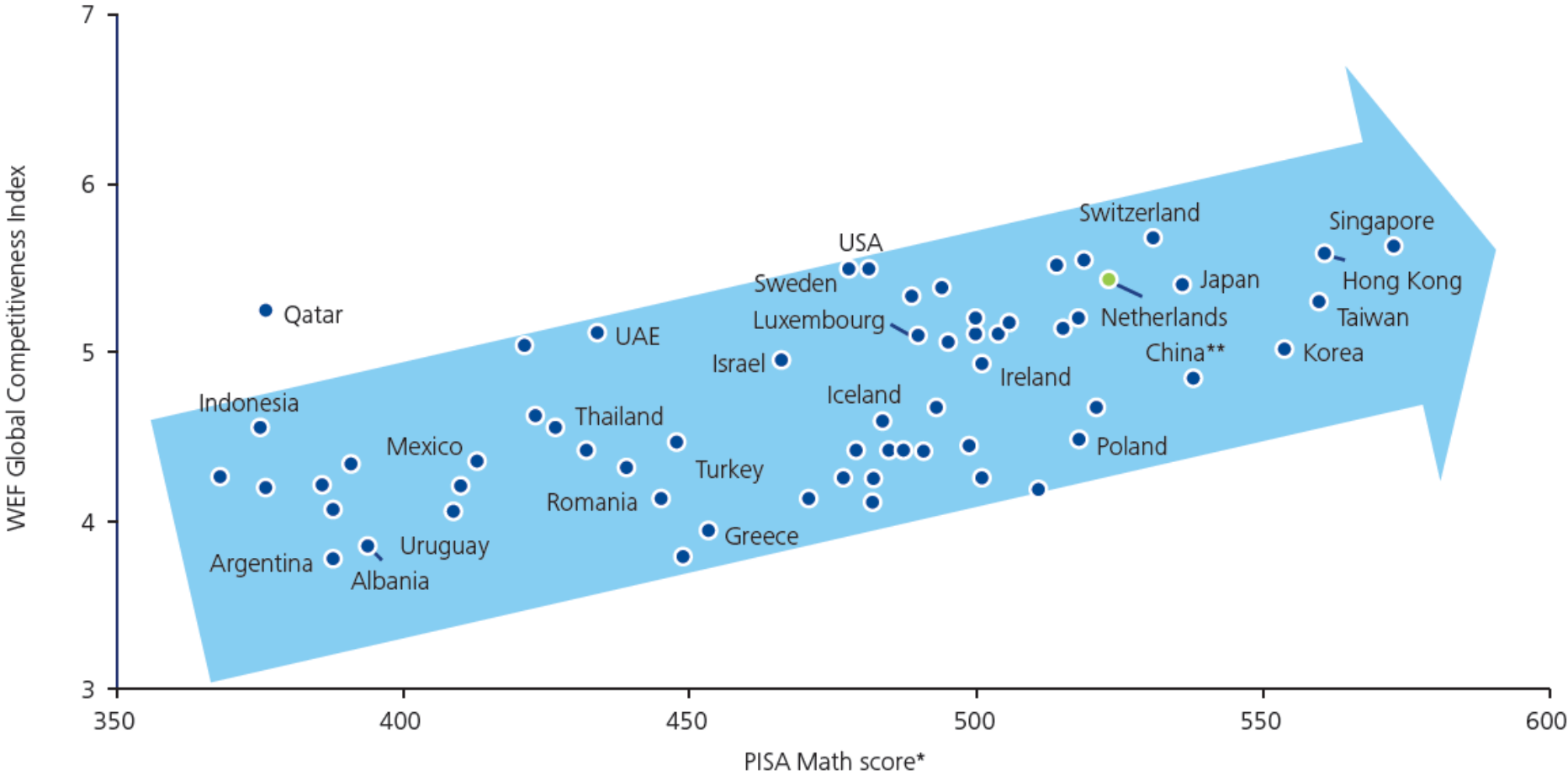


Figure 4. Relation between mathematical ability and country competitiveness



\* Mathematical ability as defined by OECD – PISA study among 15 year old  
\*\* PISA score of Macao  
Source: World Economic Forum (2013), OECD-PISA (2013); Deloitte analysis

“Revolutions in computational science, big data, statistics and analytics are likely to substantially increase the importance of mathematical sciences”

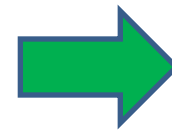
## **Recommendation 1: Policy makers and funding organisations should join their efforts to fund mathematics activities through a European Institute of Mathematics for Innovation.**

Roadmap implementation:

- EU and National funding agencies should coordinate *clusters of excellence* in industrial mathematics and create a *European Institute of Mathematics for Innovation* (EIMI) for mathematicians and users of mathematics.
- EU and European governments should set up a Strategy Taskforce for Innovation and Mathematics (STIM) in order to develop a European strategy for mathematics.
- Policy makers should put in place a Small Business Act in Mathematics (SBAM) to encourage spin-off companies explicitly using mathematics.
- EU must identify industrial and applied mathematics as an independent crosscutting priority for the Framework Programme 8.

FORWARD LOOK

Mathematics  
and Industry



ETP4MISO



# Mathematics as a Key Enabling Technology

- Key Enabling Technologies (KETs) are the main driving force behind the development of future goods and services
- Despite the undisputed role of mathematics, there is serious concern about its support in EU programs
- Mathematics has not been officially considered a KET in the official documents of the EU program HORIZON 2020
  - The situation is frequently evaluated by policy makers as no problem.
  - It is argued that mathematics is supposedly present in many projects, and the projects are to be focused as a rule not on the development of particular disciplines

EU must identify industrial and applied mathematics as an independent crosscutting priority for the Framework Programme 8.

(Recommendation 1 of ESF Forward Look project)

# Mathematics as a Key Enabling Technology

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***We strongly believe that mathematics does satisfy the criteria of Key Enabling Technology, and therefore EU-MATHS-IN is undertaking steps to achieve this status for mathematics.***



EUROPEAN COMMISSION  
ENTERPRISE AND INDUSTRY DIRECTORATE-GENERAL  
RESEARCH AND INNOVATION DIRECTORATE-GENERAL

Directors-General

Brussels, 20 DEC. 2013  
ENTR/E4-RTD/G1 (2013) 3471828

Prof. Dr. Volker MEHRMANN  
TU Berlin  
Fakultät II  
Institut für Mathematik  
room MA 466  
Straße des 17. Juni 136  
DE-10623 Berlin

Dear Prof. Dr. Mehrmann,

Thank you for your letter and for the interest you have expressed in the European strategy for Key Enabling Technologies (KETs) and the new Horizon 2020 Research and Innovation programme.

We took note of your wish to define Mathematical modelling, Simulation and Optimization (MSO) as a transversal Key Enabling Technology.

In 2009, six technologies - nanotechnology, micro- and nanoelectronics, industrial biotechnology, advanced materials, photonics and advanced manufacturing technologies - have been identified as the EU's Key Enabling Technologies (KETs)<sup>1</sup> based on research data, economic analyses of market trends and their contribution to solving societal challenges.

The analysis process involved the screening of common high-tech areas at Member State level and is based on the following criteria for selection: (1) High economic potential in terms of GDP contribution, employment and market growth; (2) Clear value adding enabling role (innovation & productivity drivers); (3) High technology intensity: highly R&D and know-how intensive, associated with rapid innovation cycles, highly-skilled employment and IPR relevant; and (4) High capital intensity: associated with high capital expenditure for initial investments, high investment per employee and high amortisation rates.

The list of KETs was endorsed by the Commission and published (Communication on KETs (COM(2009)512)) only after this analysis had been made public and had been widely discussed.

<sup>1</sup> See COM(2009)512 "Preparing for our future: Developing a common strategy for key enabling technologies in the EU". The Communication is complemented by the Staff Working Document "Current situation of key enabling technologies in Europe" that explains why advanced materials, nanotechnology, micro- and nano-electronics, industrial biotechnology, photonics and advanced manufacturing systems have been identified as priority areas for improving European industrial competitiveness. SWD(2009)1257.

Considering the above mentioned specificities, policy makers clearly needed to put in place the right framework conditions and support instruments for strengthening the EU's industrial capacities for the development and deployment of the six identified KETs.

While we certainly acknowledge the importance of Mathematical modelling, Simulation and Optimization (MSO), not all KETs criteria mentioned above are applicable to them.

However, it is indeed clear that Mathematical modelling, Simulation and Optimization are an important issue in today's research activities. MSO activities have been introduced in various parts of the Horizon 2020 Industrial Leadership draft work programme, for example in nanotechnologies and materials and Private-Public Partnership topics, such as Factories of the Future that are also widely resorting to modelling. The programme was adopted by the Commission in December.

Additionally, in order to tackle the issue in a strategic and forward looking manner in future years, we would like to suggest that you discuss the issue directly with our services during the first months of 2014. We also suggest that you coordinate amongst yourselves to allow our services to facilitate contacts.

Yours sincerely,

Daniel Calleja

On behalf of  
Vice-President A. Tajani,

Robert-Jan Smits

On behalf of  
Commissioner Geoghegan-Quinn

**Only a combined effort via  
EU-MATHS-IN has the  
potential to be successful**

2016

# Consultations Excellence in Science

●●●● Proximus 

18:54

ec.europa.eu

## Consultations

In preparation of Work Programme 2018-2020.

### FET Flagships

Share your ideas about grand Science and Technology Challenges for Europe.

### FET Proactive

Share your ideas about new game-changing future technologies.

### Mathematics

Inform the future work programmes with innovative mathematical content.

### e-Infrastructures

Identify the key challenges of the future e-infrastructures.

## Quick links

### FET

Future and Emerging Technologies

### Citizen Science

Science for the people, by the people

message, loud and clear, that mathematics have a lot to offer to science innovation. The response has exceeded expectations both in terms of quantity of and in the quality of contributions received.

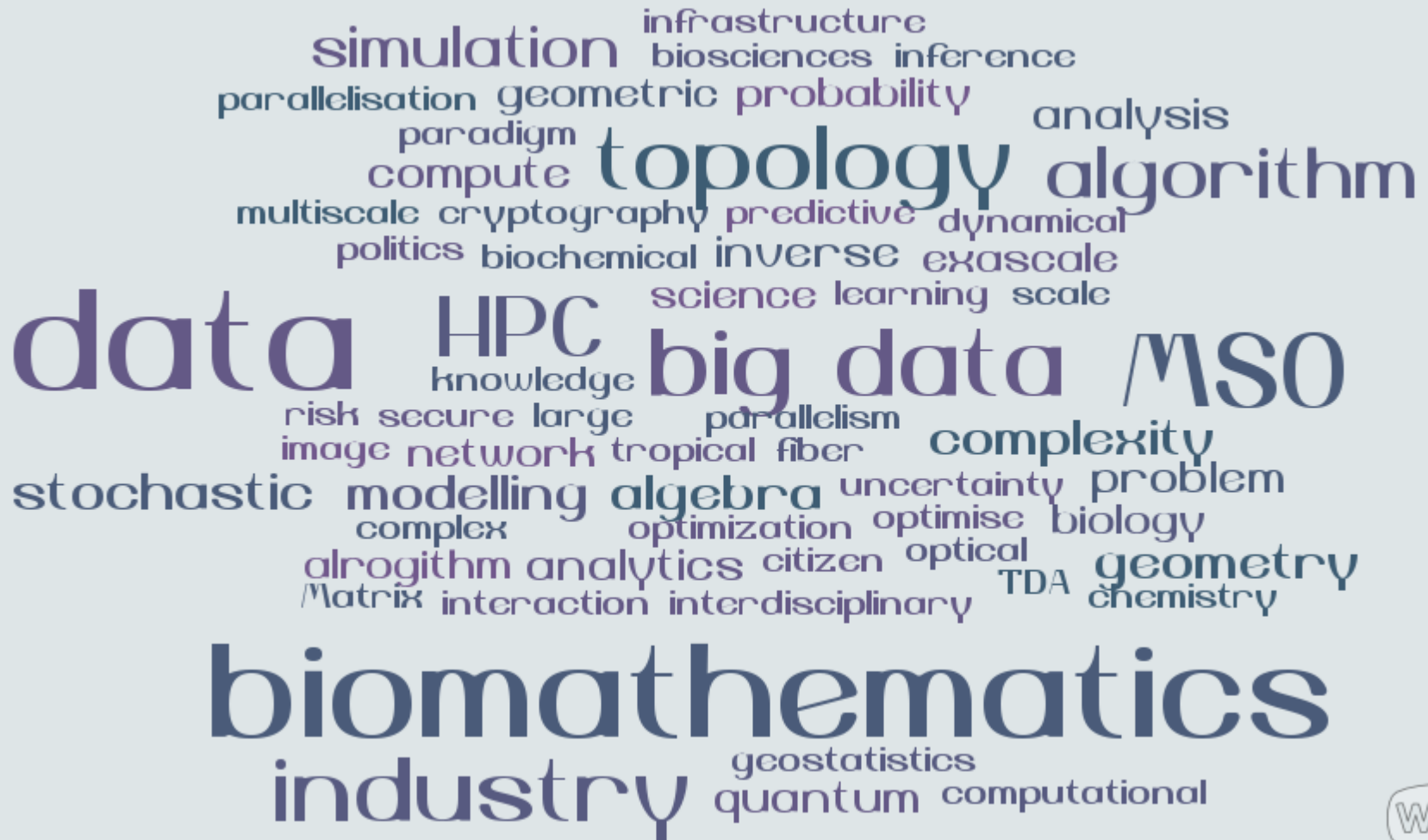
### What are the challenges for tomorrow's e-infrastructure?

The process towards the third and last Horizon 2020 Work programme covering the period 2018-2020 has started, and we would like you to help us identify the challenges faced by the European e-infrastructure stakeholders. What are the key challenges? How to answer the increasing scientific demand? How can industrial actors fully benefit from services provided by European e-...

### Want to talk innovation? Check out the Innovation4EU debates!

Innovation is multi-flavoured. It can be digital, open, responsible, social or industrial, disruptive or data-driven. Innovation brings creativity and knowledge, it drives data and research. Innovation is everywhere. But where does Europe stand? How can we become more innovative in order to be more...

# The report, shortly:



## Next steps



**Session on mathematics**  
**27 September 14:00-14:45**

Focus:  
**all DG CONNECT H2020**  
**Work programmes 2017**

Objectives:

- **Proposers and mathematicians to find each other**
- **Mathematical partners into relevant consortia!**

<https://ec.europa.eu/digital-single-market/en/ict-proposers-day-2016>

# A new 3-letter acronym: MSO

**MSO = Mathematical Modelling, Simulation, and Optimization:** it entails

1. a mathematical model (a set of equations) that captures the conceptualization;
2. a simulation that implement this model and captures the visualization (making invisible things visible);
3. an optimization that enhances the design process (making the design realistic and optimal).

**MSO contains the entire  
mathematical machinery!**

# Importance of MSO

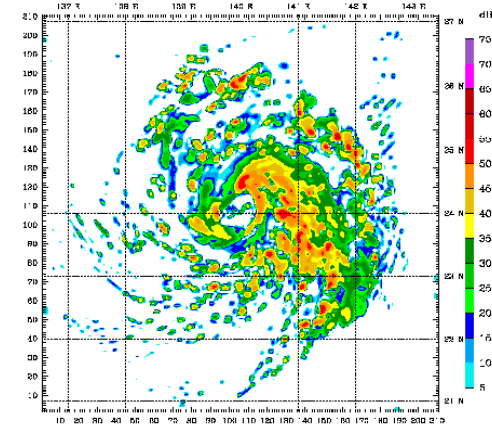
- MSO is an extremely important ingredient in our innovation-driven society
- It requires cooperation between many different disciplines in order to produce accurate models, efficient simulation algorithms and reliable optimization techniques
- MSO requires the **involvement of mathematicians** at all levels – they will have a decisive contribution → introduction of novel methods and concepts (e.g. UQ)
- Timo Hallantie (FET director): “Mathematics is often the missing component in projects.”

**MSO is a key enabling technology**



# MSO/Mathematics for innovation

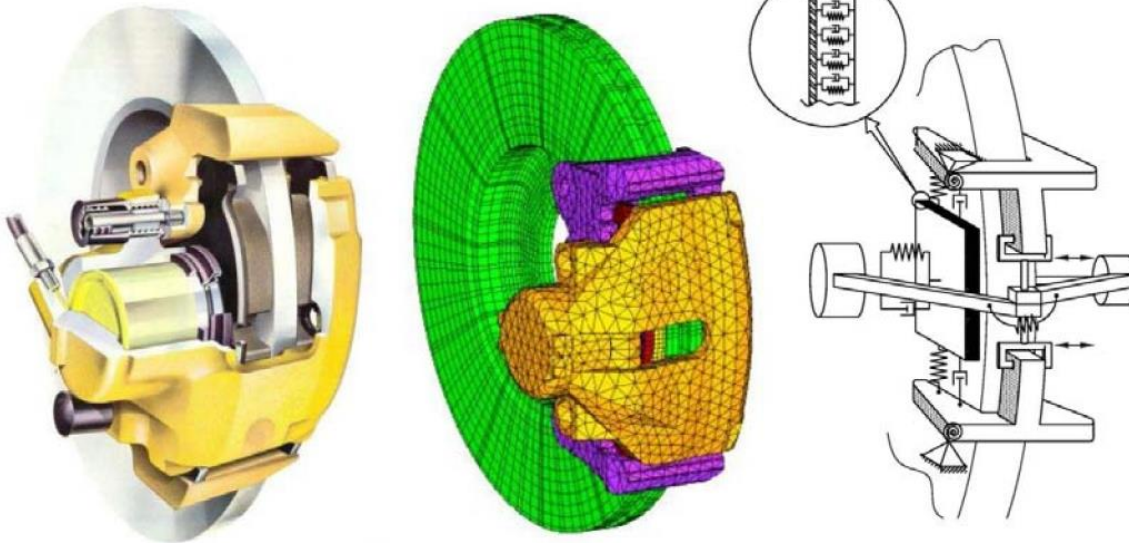
- Our approach to **modelling, simulation and optimization (MSO)** is to work with the client to understand the system fully...
- ...then abstract it to a form which is amenable to mathematical treatment...
- ...and build a modelling framework or simulation of the system to allow levels of increasing complexity, optimization of designs, what-if scenarios, and trade-offs to be explored.



Mathematicians will be part of the team – addressing the challenge together

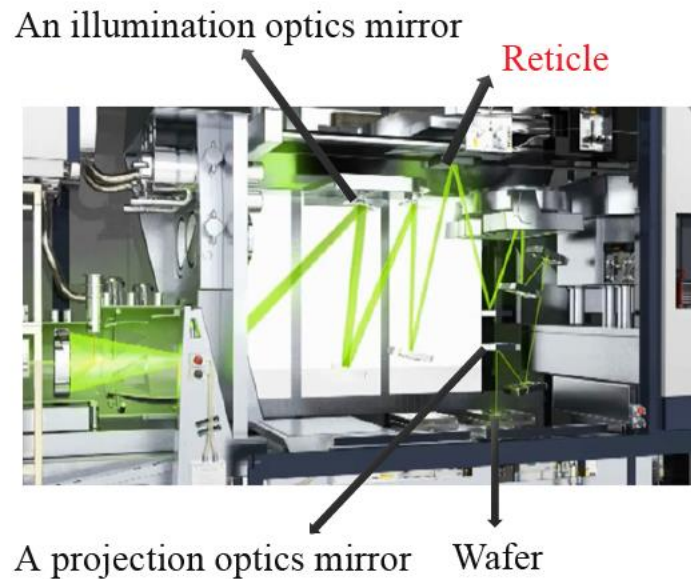


# Disk Brake squeal (Volker Mehrmann)



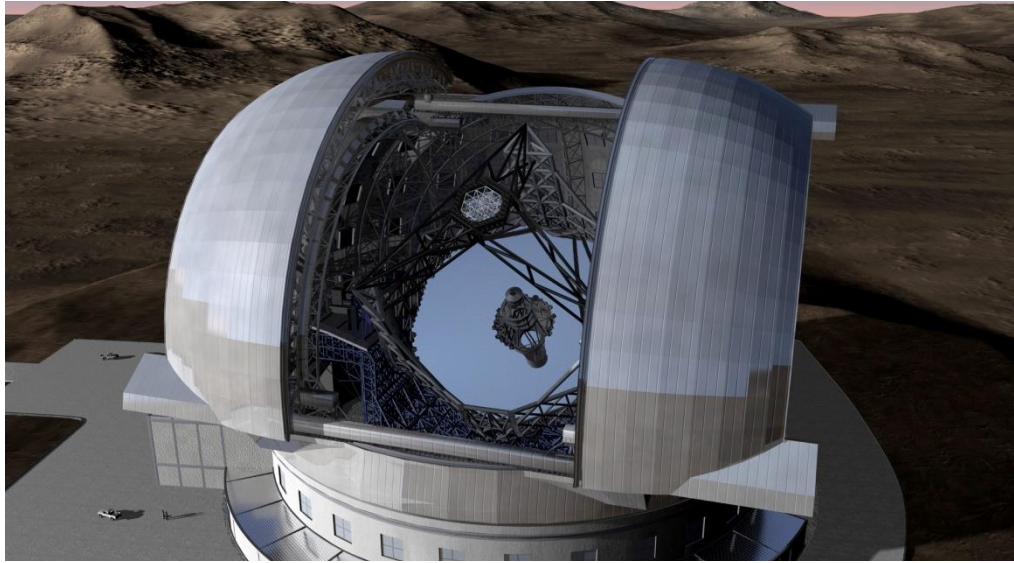
- Thirty years of trial and error by engineers, recent progress based on **mathematical modeling** and **simulation** (Matheon)
- Car makers standing in line to obtain new nonlinear models

# ASML wafer stepper



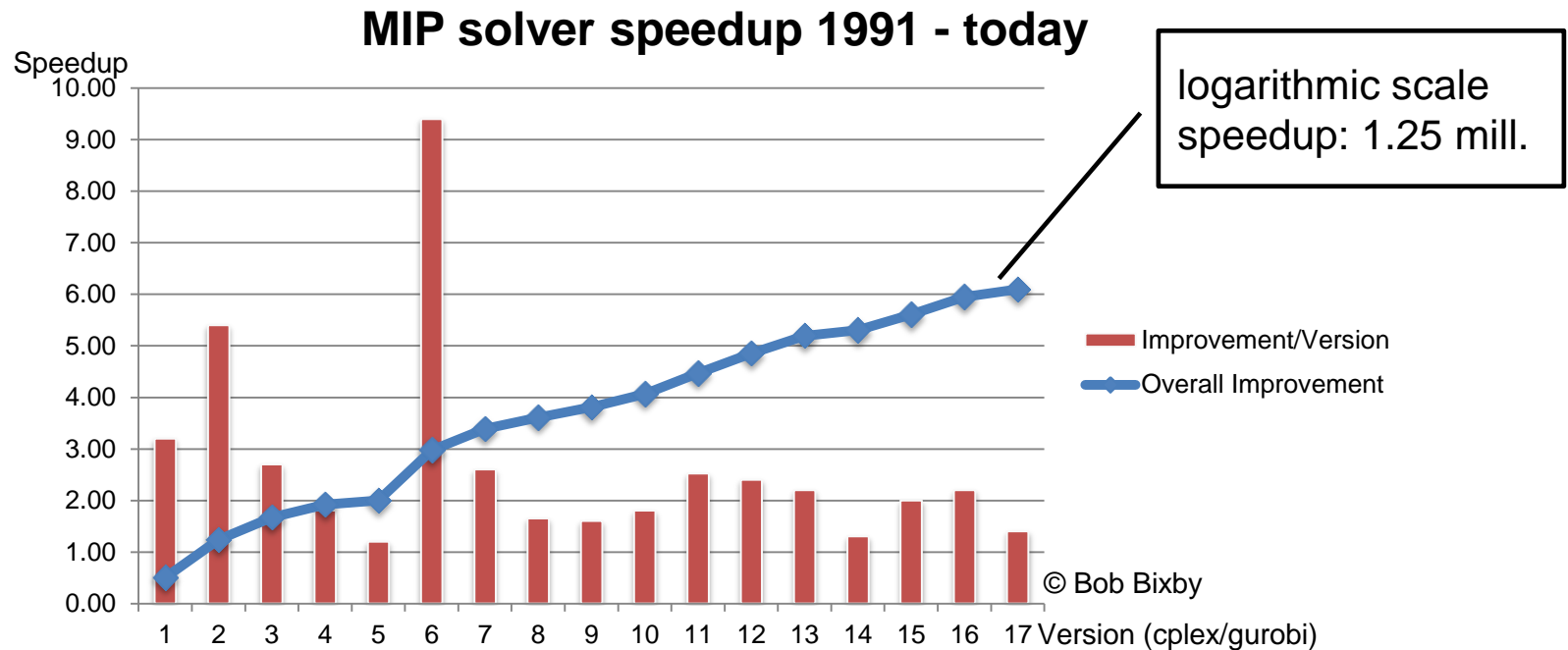
The challenge is to combine thermal, mechanical, electromagnetic effects so as to arrive at the desired highly accurate parameterized models supporting the complex control systems

# XL Telescope



- The European Extremely Large Telescope (E-ELT), planned by the European Southern Observatory (ESO), will be the biggest telescope on earth (first light: 2022)
  - Image quality of the E-ELT relies on Adaptive Optics (AO) techniques
- 
- AO systems have to compute the optimal shape of deformable mirrors up to 3000 times per second (whole night!)
  - For the planned eXtreme Adaptive Optics system of the E-ELT it has been estimated that the computing power available at the telescope in 2022 is not sufficient to compute the deformable mirror shapes within 0.3ms using available mathematical algorithms
  - Since 2009 in Austria: development of **new mathematical** algorithms
  - **2014: new reconstruction algorithms** that compute the optimal mirror shapes in the available timeframe **on todays hardware! Speedup-factor: 800-1000!**

# Progress in Mathematical Algorithms



Progress in machine speedup 1991 - today: 1,600

**Algorithms  
outperform  
machines!**

That is, problems that are solved in 1 second today could not be solved 25 years ago within 75 years

**THE FUTURE**

**Towards  
a European Technology Platform  
for Modelling, Simulation, Optimisation**



# What are European Technology Platforms?

- European Technology Platforms (ETPs) are industry-led stakeholder fora recognized by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness.
- ETPs develop research and innovation agendas and roadmaps for action at EU and national level to be supported by both private and public funding. They mobilize stakeholders to deliver on agreed priorities and share information across the EU.



# What do ETPs do?

- developing industry-focused **strategic research and innovation agendas** including technology roadmaps and implementation plans;
- encouraging industry participation in Horizon 2020, the EU's framework programme for research and innovation, and cooperating with networks in Member States;
- fostering networking opportunities with other ETPs and other partners along the value chain to address cross-sectoral challenges and promote the move towards more open models of innovation;
- identifying opportunities for international cooperation;
- acting as one of the channels of external advice for the programming and implementation of Horizon 2020; notably, ETPs have been a key driving force behind the launch of high profile public-private partnerships under the programme.

# Currently 41 ETPs

- **38 contained in 6 main areas:**

- Bio-based economy (7)
- Energy (8)
- Environment (1)
- ICT (9) amongst which ETP4HPC
- Production and processes (8)
- Transport (5)

- **3 cross cutting ETPs**

- Nanofutures, Industrial Safety, ConXEPT



# Towards ETP4MSO

- Two workshops in Amsterdam (July, October) with industrial partners to define the scope of ETP4MSO and gather support (**industry must be in the driving seat**)
- Core team of industry people formed, meeting every week
  - Siemens, Shell, Dassault, Michelin, EY, Repsol, Nors
- Visits to Brussels to discuss the formation of an ETP4MSO (January 2018, DG Connect)
- Combined research/innovation workshop in Lorentz Centre, Leiden from December 11-15: **“Future and Emerging Mathematical Technologies in Europe”**
- **Vision document** and **Strategic Research Agenda** early 2018
- We will be fully prepared for FP9 (follow-up of H2020)



# European Service Network of Mathematics for Industry and Innovation

## European Technology Platform

### Virtual Twins

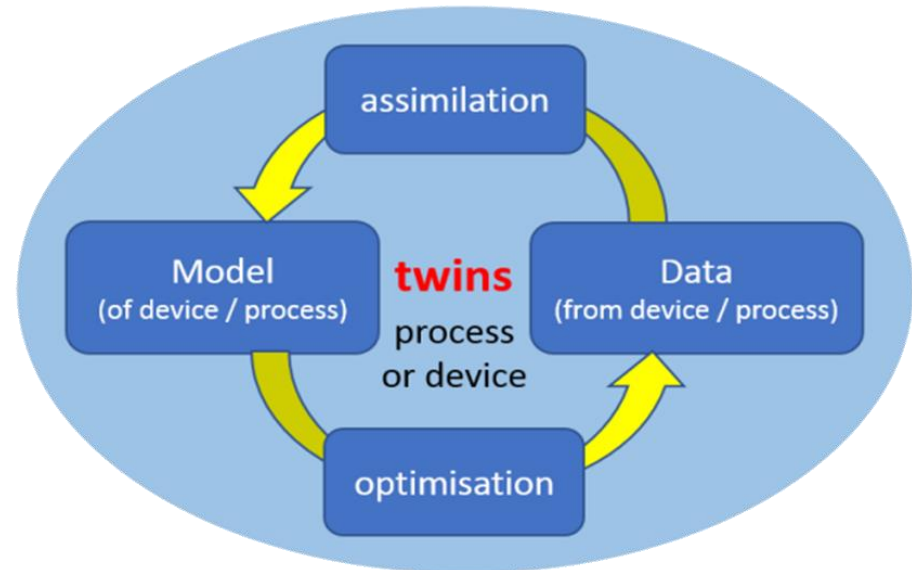
*Modelling, Simulation, and Optimisation from  
a Data poor to an integrated data rich  
Environments (MSODE)*

# Today's challenges

- **Complexity of products** and systems is increasing and at the same time **innovation cycles get shorter** and shorter.
- This **requires new engineering and operations paradigms**, methods, and tools going beyond purely MSO or artificial intelligence approaches.
- There is a clear need to **strengthen European competitive advantage** in computational methods keeping its head start
  - Europe has a strong history in simulation-based sciences

# Our Vision: Virtual Twins

- The whole life cycle of a product or (industrial) process, starting from its conception, will be managed through **twinning with a virtual representation**.

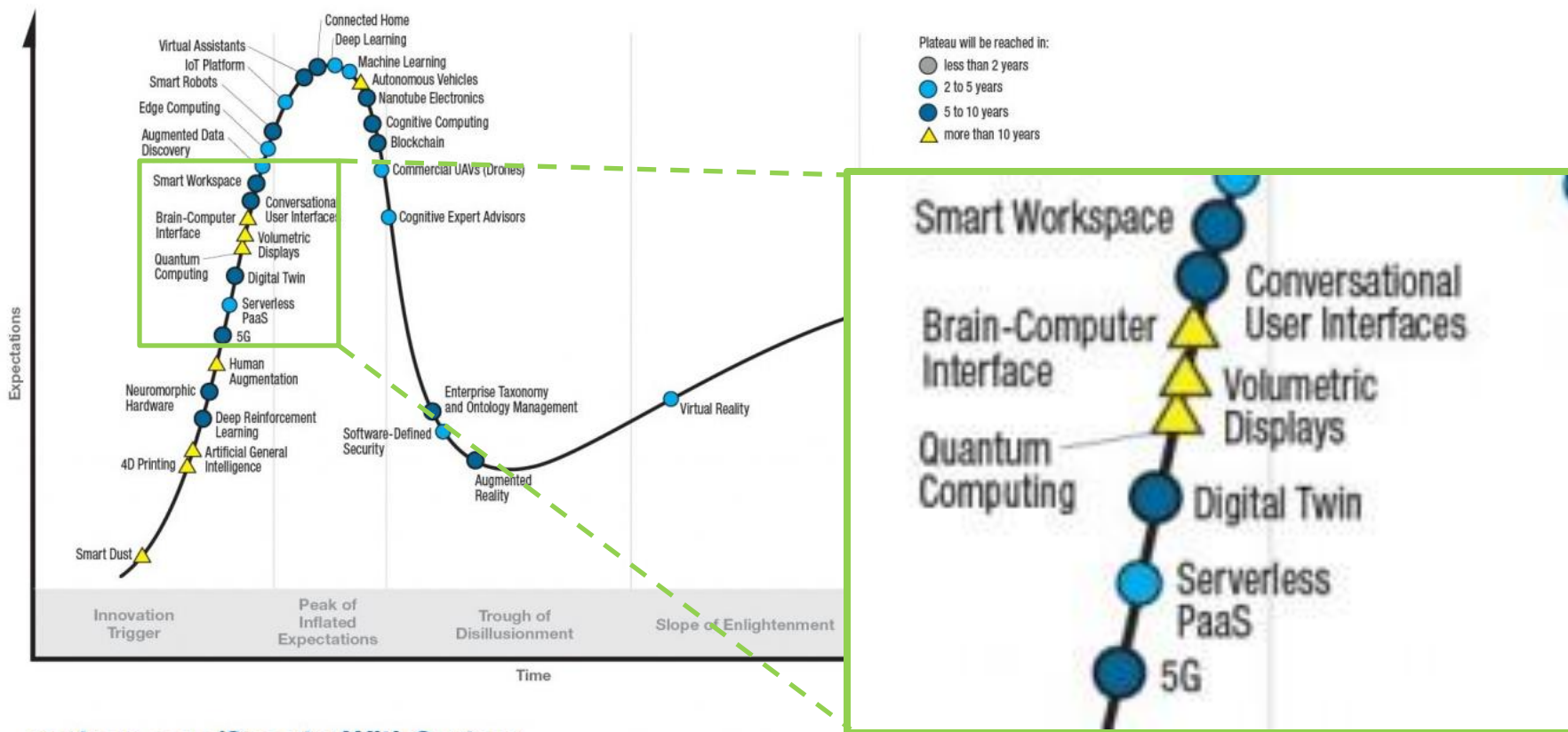


- These provide **assistance** for users **based on MSO technology** guiding through the world of exploding complexity.

# Excursion: Digital Twins

<https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/>

## Gartner Hype Cycle for Emerging Technologies, 2017



[gartner.com/SmarterWithGartner](https://www.gartner.com/SmarterWithGartner)

Source: Gartner (July 2017)  
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# Goal of the initiative

- Today's **algorithmic research is split-up** according to the different life cycle phases of a product or system. To master future challenges, **a seamless unified and systematic approach is required.**
- **Europe has a strong history** in engineering and a world-wide recognized track record in the simulation-based sciences. Therefore Europe is the right hub to foster the next generation of MSO tools, concepts and paradigms
- With this initiative we want to ensure that a **strategic research agenda** is being set up to foster Europe's competitive edge and go beyond today's approaches.



# Conclusion

- MSO (mathematical modelling, simulation and optimization) is a **key enabling technology** for innovations and challenges in industry and society, and **must be recognized as such**
- Close cooperation with HPC, exascale and Big Data communities (e.g. ETP4HPC, EXDCI) is vital
- Establishing a European Technology Platform for MSO is key in driving mathematics in Brussels

**INDUSTRY SUPPORT IS VITAL  
IN THIS ENTERPRISE**

