European Cooperation in the field of Scientific and Technical Research
- COST -

Brussels, 14 November 2014

COST 118/14

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action TD1409: Mathematics for industry network (MI-NET)

Delegations will find attached the Memorandum of Understanding for COST Action TD1409 as approved by the COST Committee of Senior Officials (CSO) at its 191th meeting on 12-13 November 2014.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action TD1409
MATHEMATICS FOR INDUSTRY NETWORK (MI-NET)

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 "COST Action Management" and document 4112/13 "Rules for Participation in and Implementation of COST Activities", or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to facilitate more effective widespread application of mathematics to all industrial sectors.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 56 million in 2014 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Section *2. Changes to a COST Action* in the document COST 4114/13.

GENERAL FEATURES

Initial Idea:

Mathematics underpins the whole of modern science and technology. However, the knowledge and understanding of mathematical concepts that is contained within universities is very poorly exploited. The UK's Knowledge Transfer Network in Industrial Mathematics and the Mathematics of Information Technology and Complex Systems (MITACS) in Canada are perhaps the best examples where mathematical expertise is harnessed and used successfully to improve a wide range of industrial process, and so provide a competitive advantage. Inspired by these examples, this Action aims to create a Europe-wide partnership to promote collaboration in, and the benefits of, industrial mathematics.

The Action will run, industry workshops, training weeks, and short-term scientific missions (to both academic and industrial hosts), with the general aim of increasing the interaction between industry and academia. Exploiting the mathematical knowledge and methodologies of academics will provide European industry with a competitive advantage. Universities will benefit, as mathematicians are able to focus on practically relevant and cutting edge research problems. The training of Early-Stage Researchers in particular will lead to a new generation with problem solving and communication skills and collaborative links that will be essential to maintain the goals of this Action in the future long after this funding has finished.

Keywords: industrial mathematics, technology transfer, knowledge transfer, applied mathematics, mathematics applications, mathematical modelling, problem-solving, scientific computation, simulation, technology translation, interpretation, quantitative analysis, problem-refinement, mathematical specification/description.

A. CHALLENGE

A.1 Background and Motivation

Mathematics underpins all of modern science and technology. However, advances in mathematical research are not always applied to maximum advantage in industry. The objective of this Action is to facilitate more effective widespread application of mathematics to all industrial sectors - from

medicine to entertainment and social networks to security - thereby increasing economic output and the well-being of society.

Industrial mathematics is a diverse and problem-driven research area, which has been shown time after time to provide a competitive advantage and produce significant innovation. However, despite an enormous increase in activity in this area over the last forty years, industrial applications of mathematics tend to be clustered, both geographically and sectorally. There are still many European countries in which the potential of mathematics to create models for fundamental understanding, simulation, optimisation, and prediction is not exploited. There are also many subject areas in which the mathematical approach has yet to be fully developed, such as nanotechnology and social science. European businesses compete in a global market, and there are many regions outside Europe where manufacturing and labour costs are much lower. To be globally competitive, Europe must rely on innovation. According to the Organisation for Economic Co-operation and Development's 2008 Report on Mathematics in Industry, “Industrial innovation is increasingly based on the results and techniques of scientific research. That research, in turn, is both underpinned and driven by mathematics”.

The rewards of developing a successful interface between academic mathematicians and industry are tangible and mutually beneficial. Industry provides a fertile source of new and interesting scientific problems, often resulting in the development of new mathematics. Mathematics can provide insights that allow industrialists to improve their products and processes (resulting in a reduction in production costs, defect rates, and waste, and/or an increase in the throughput of physical processes), and reduce the amount of costly and time-consuming experimentation needed to develop new processes. Small or Medium Enterprises (SMEs), in particular, often do not have the resources to exploit mathematics for themselves.

In the last decade, several reports solely on Mathematics for Industry have been published. Two of the most recent reports include the Society for Industrial and Applied Mathematics (SIAM) Report on Mathematics in Industry (2012) and the European Science Foundation sponsored Forward Look on Mathematics and Industry (2011). These reports have been based on international consultation, and have compiled surveys of mathematics PhD graduates and interviews with senior industrialists. All these reports are unanimous on the multiple benefits of a strong interface between mathematicians and industry, but that there is a pressing need to boost existing activity.

The objectives of this Action are to encourage interaction between mathematicians and industrialists, in particular through

1. industry-driven problem solving workshops, and

2. academia-driven training and secondment.

A.2 State of the art

Existing organisational structures

The European Consortium for Mathematics in Industry (ECMI) is a consortium of 85 universities, from 23 EU countries, who work together to promote industrial mathematics across Europe. Together they have created a Model Masters Programme in industrial mathematics to train young researchers in the skills needed for working in teams on real problems and this now forms the basis of many masters' programmes in universities. ECMI organises one mathematical modelling week a year for young researchers a biennial conference, and publishes a semi-annual newsletter. However, ECMI is entirely coordinated by volunteers and has no funding available for running any additional activities. The European Mathematical Society (EMS) is a professional society for mathematicians working in Europe. Although the majority of its members work in pure mathematics, the EMS Applied Mathematics Committee has made significant contributions towards the progress of Industrial mathematics in Europe through its Forward Look report and European Success Stories in Industrial Mathematics. Although the Committee does not currently have sufficient resources to implement many of its recommendations, it will provide a useful forum for establishing new contacts and disseminating news about the activities of this COST Action.

Some European countries have their own national organisations for industrial mathematics. For example, in the UK, the Knowledge Transfer Network (KTN) in Industrial Mathematics has been used successfully to bring the best expertise available in British universities to bear on the problems of industry. It has established co-funded programmes with industry, including internships and postgraduate studentships, to enhance UK industry and to produce students trained to work in industrial research. In Germany the Fraunhofer Institute in Industrial Mathematics is closely allied with the University of Kaiserslautern and has strong links with German industry. In the Netherlands the 'Platform Wiskunde Nederland' is funded by university departments and the Dutch funding organisation (NWO) for basic research, and one of its aims is to 'improve the links between scientific mathematics and innovative applications in industry'. The project 'i- MATH' has been successful in promoting mathematics in science, technology and business in Spain. However, in the majority of European countries there is little or no interaction with industry in spite of there being highly trained mathematicians in the universities.

Problem-solving workshops ('Study Groups')

Different methods to create collaborative links between mathematicians and industrialists have been devised in different countries.

One mechanism that has proved particularly effective in creating links between mathematicians and industrial scientists is the “European Study Group with Industry” programme. Since its initiation in Oxford in 1968, the Study Group format has become an internationally-recognised problem-solving forum for knowledge transfer. Industrialists bring a problem to one of these week-long brain-storming workshops which are attended by a group of mathematicians with varied expertise. By the end of the week a mathematical approach to the problem has been identified and a strategy for further work can be devised.

Study groups have attracted companies from all sectors and of all sizes, including household names such as Philips, Unilever, IBM, and Kodak. The workshops also provide a convenient and low-risk method for SMEs to access academic expertise. Both the number and diversity of problems addressed is impressive. There are over 500 technical reports on the International Study Groups Website on problems as diverse as optimising the layout of car parks, reducing vibrations in aircraft landing gears, and improving fraud detection. Industrial mathematics typically encompasses many topics, from fluid dynamics to operations research; however these diverse topics are often linked by fundamental commonalities. By gathering together mathematicians from a wide range of backgrounds to solve a variety of industry problems, these commonalities can be exploited and the potential for technology transfer is maximised. Similar types of workshop are now organised all over the world, including in Australia, China, the US, Canada, South Africa, and themed study groups to promote collaboration between mathematicians and life scientists have been successful in the UK.

Training and secondment

To familiarise young researchers with some of the standard techniques of industrial mathematics, the idea of a mathematical modelling week was devised, and these are often held the week before a Study Group. The typical format is for about 6 young researchers per team to work on carefully prepared real-world problems. Young researchers are advised by experienced researchers who have strong track records of successful collaboration with industry and act as excellent role models. Modelling weeks provide excellent experience of working with peers from different countries and backgrounds (embodying the ever-increasing internationalisation of Europe), as well as helping to develop strong problem-solving and communication skills. Several mathematical modelling weeks are organised per year across Europe, though these workshops are always very oversubscribed.

MITACS, the Mathematics of Information Technology and Complex Systems, in Canada, runs a very successful research internship programme, Accelerate. Young researchers spend approximately 3-6

months on industrial placement working on short stand-alone projects. The objectives of this initiative are to give young researchers valuable experience of research methods in industrial settings, enhance career prospects, transfer academic techniques to industry, and import industrial skills into universities. A similar scheme is organised by the KTN in the UK, but this mechanism for industrial mathematics knowledge transfer has huge potential for expansion.

A.3) Challenges

Uneven distribution of industrial mathematics activity across Europe

European Success Stories in Industrial Mathematics was published by Springer in 2012 and is a collection of case studies collected by the group who produced the Forward Look on Mathematics in Industry. It contains brief descriptions of 130 case studies. The case studies are spread across 6 industrial sectors: health and biology; energy and environment; finance and modelling; automotive industry and manufacturing; aerospace and electronics; services, transport and logistics, however case studies of mathematics research in, for example, food and drink are notably absent. The case studies come from 15 different countries but over 70% of them are from 5 countries (France, UK, Italy, Germany, and Spain). The report demonstrates both the effectiveness of mathematics in tackling a wide spectrum of problems, but also the uneven spread of the activity within Europe.

Since 1993, 70 study groups have been hosted in Europe and there are now regular workshops in 5 countries (UK, Portugal, Netherlands, Denmark, and Ireland). The 100th European Study Group was hosted in the UK in April 2014. However, relatively few study groups have been held in Central and Eastern Europe and the Mediterranean countries. One of our goals is therefore to facilitate the spread of this well-established method of academic-industrial interaction in mathematics more widely across Europe.

Invisibility of mathematics - “Invisible contribution, visible success”

In principle, there are no limits to the problems that can be tackled using mathematics. However, mathematics is often viewed by industry as an esoteric subject of little practical use. Most companies are not aware that they have a problem that can be solved using mathematics, and that many everyday problems can be cast in mathematical terms: “Mathematics is an essential factor in the industrial creation of value ... but often, its contributions are invisible in the final industrial products.” (2010 Forward Look on Mathematics in Industry).

Cultural incompatibility

One particular problem is that mathematics is often applied at an early stage of the product development process; therefore industrialists may be reluctant to commit many resources into what is seen as a speculative endeavour. Another challenge is that project timescales in industry tend to be much shorter than those of academia. More flexible and more varied modes of engagement between academia and industry are required to enable industrial research within constraints of limited time and financial resources.

Insufficient numbers of trained graduates

Europe is not producing sufficient graduates in Science, Technology, Engineering and Mathematics (STEM) subjects. Reporting on remarks from the chief executives of Volvo and Siemens, two of Europe's biggest manufacturers, the Financial Times (May 2013) noted "alarm over a growing skills shortage on the continent that threatens their competitiveness", forcing companies "to move more research and development facilities to countries such as China or India." The 2011 Business Europe report identified the lack of STEM-skilled labour as "one of the main obstacles to economic growth in the coming years." (Plugging the skills gap – the clock is ticking.)

However, solely academic mathematics training is insufficient in equipping graduates with the necessary skills to solve real-world problems. Industrial experience, the ability to formulate a qualitative problem in mathematical terms, and strong transferable (in particular communication) skills are essential to ensure the next generation of mathematicians is capable of applied research in an academic or industrial environment. "It is not enough to have a good idea; they need to sell it in a language that management will understand." (2012 SIAM Report on Industrial Mathematics.)

Therefore, the key challenges that this proposal will address are

1. The potential value of mathematics is not fully exploited by European industry.
2. There is a shortage of young researchers in mathematics trained to work in industrial research.

Actions to address the challenges:

I. Coordinate existing national efforts in industrial mathematics, and provide practical assistance and financial support to roll out similar schemes in new countries.

II. Increase industry's awareness of the benefits of mathematics throughout Europe.

III. Make contacts between academia and industry more effective – by disseminating best practices for industrial liaison (including account management and the key principles of business development).

IV. Train more young researchers by offering training with hands-on problem-solving experience to young and Early Stage Researchers (ESRs) – via STSMs to industrial hosts (especially for SMEs) and collaborative problem-solving activities such as Study Groups and modelling weeks.
V. Strengthen young researchers' transferable skills and collaboration networks by seed funding international Short-Term Scientific Missions to academic hosts.

Relevance and Timeliness

This Action is particularly timely: Europe has played a leading role in initiating Industrial Mathematics, but the rest of the world is now rapidly catching up. There are very active networks operating in Australia and Canada, for example. Initiatives in India and China have been active for several years and government-funded programmes are currently being established in Brazil and Malaysia. In SIAM News 2013, the President of SIAM remarked, "we need to re-energize and reinforce our efforts with the two I's of SIAM; Partnering with Industry and deepening our international network". By coordinating and promoting activity, and training the next generation of industrial mathematicians, this Action can help Europe keep its competitive advantage.
There are also several topics – such as complex networks and data analytics – that have recently seen significant increases in commercial interest, and mathematics has a huge potential role to play in these areas.

A.4) Impact

Scientific impact

The scientific novelty is two-fold: the development of new mathematical techniques to solve industrial problems (long- term impact); and the application of mathematical techniques to the solution of new scientific and technological problems (short-term impact).
Innovative mathematics will need to be devised to solve the problems that arise, and this will lead to joint publications in learned journals. Study Groups have a strong track record of taking research through to the publication stage, see for example, the recently-founded academic journals Mathematics-in-Industry Case Studies and the Journal of Mathematics in Industry.
Free boundary problems, partial differential equations to be solved for an unknown function over an unknown domain, are an expository example of how industrial problems can stimulate new areas of mathematical research. The area burgeoned in the 1970s after a large number of problems from industry, including electrical painting, groundwater flow, solidification and melting, were found to

fall into this category. A Google Scholar search for 'free boundary problems: theory and applications' now gives 1.5 million results, and there is a dedicated interface and free boundaries journal.

Inverse Problems, often known as "parameter identification" problems in industry, are another example of an area of mathematics which have been stimulated by industrial applications. The canonical problem is from the oil (or other mining) industry and concerns finding out where the oil/gas/coal is from seismic measurements at the surface. But many other problems turn out to be of inverse type - whenever you are trying to calculate parameters from limited (either in space or time) data you have an inverse problem which probably does not have a unique solution.

Often mathematical models or techniques devised for one application can be applied to another, seemingly unrelated, application or setting. This knowledge is conserved by mathematicians and that is why study groups are often so successful. “Technology transfer, including the transfer of mathematical ideas, is not a one-way street; a technology designed for or by one company often ends up enriching science as a whole.” (2012 SIAM Report on Mathematics in Industry.)

An archetypal example occurred in mathematical finance. Mathematical Option Pricing received a huge intellectual boost when it was realised in 1973 that the Black-Scholes equations were almost identical to the equations for solidification of steel (both are free boundary problems for a diffusion equation). This resulted in the exploitation of a vast body of existing literature going back decades, and has led to a number of researchers in partial differential equations and fluid mechanics turning their attention to financial problems.

Societal impact

Universities in this COST Action will act as centres of cooperation. Industry problems often require a range of expertise, not always to be found within a single mathematics department, or even within a single country. The Action will simplify the process of finding the best partners for relevant EU projects, as well as providing mentoring support for researchers new to the process. This will result in increased participation of less research-intensive countries in Europe.

Economic Impact

Mathematics has huge potential for producing large savings for industry. A 2012 report, commissioned by the UK Engineering and Physical Sciences Research Council (EPSRC), estimated the contribution of Mathematical science research to the UK economy in 2010 to be 2.8 million jobs (around 10% of all jobs in the UK) and £208 billion in terms of Gross Value Added (GVA) contribution (around 16 per cent of total UK GVA). This Action will enable many more industrial problems to be solved or brought to the development stage.

Filling the skills gap and capacity building

Mobility within the Action will provide Early-Stage Researchers access to hands-on mathematical modelling training workshops, with an emphasis on enhancing their communication skills. COST funding will assist researchers from the countries that do not currently run these activities to participate in those organised by other institutions, and seed new initiatives in many research centres. This will result in increased numbers of Early-Stage Researchers in mathematics highly trained to work on interdisciplinary problems. This Action will provide financial support for young and Early-Stage Researchers to visit established industrial mathematics research centres and industrial partners. Long-term benefits of this initiative will be an increased number of mathematicians realising the rewards of an industrial mathematics career in industry or academia.

B. ADDED VALUE OF NETWORKING

B.1 International coordination is the key to success

There is currently an uneven distribution of industrial mathematics activity across Europe. The objective of this COST Action is to address this imbalance and thereby achieve an increase in industrial problems solved and an expansion of research in industrial mathematics.

In countries where industrial mathematics is well established, researchers are keen to establish links with new centres and to tap into the mathematical resources of young and Early Stage Researchers. In countries where mathematics in universities is very theoretical, researchers would like assistance with establishing industrial collaborations.

Industry problems often require range of expertise, not always to be found within a single mathematics department, or even within a single country. Stronger communication between existing activity in industrial mathematics and emerging efforts in COST Inclusiveness Target Countries is vital for identifying important areas in which to focus research efforts: "... the creation of national and international networks can both stimulate mathematical awareness and creativity concerning industrial problems and avoid duplication of intellectual effort." (OECD Report on Mechanisms for Promoting Mathematics-in-Industry 2009.)

How this COST Action will add value

This COST Action, through establishment of regular Study Groups, themed one-day workshops, STSMs and Modelling Weeks, will increase activity in industrial mathematics across Europe, in particular in countries which have little track history in the area. A strengthened coordination of activities will ensure a cohesive European effort in industrial mathematics.

Increasing awareness of mathematics in industry

Often, the first difficulty in industrial mathematics is getting across the idea that a mathematician might be useful. Technical reports, case studies, and publicity generated by this COST Action will help to spread awareness of the benefits of mathematics.

Increasing communication between mathematicians

There is often an overlap between industrial problems in different countries, and also in different industrial sectors. Repurposing an existing solution is likely to be quicker and cheaper than starting again from first principles. Stronger transnational communication between mathematicians will reduce the risk of duplication of effort and increase the technology transfer between application areas.

Increasing awareness of industry problems in mathematics

The themed one-day workshops funded by this COST Action will enable mathematicians to identify and classify the types of problem that occur in different industries. By focussing these workshops on industrial topics where mathematics has yet to be employed to full advantage, mathematicians will be encouraged to apply their knowledge and skills in new areas. Countries with less activity in industrial mathematics will be prioritised as locations for these workshops.

Connecting industrialists with relevant international experts

Suitable mathematical expertise is often missing in many companies, particularly SMEs. Industrialists find it easier to work with academics in their own country, although in countries with little or no tradition of putting academic mathematicians to use in industry, a suitable expert in the relevant branch of mathematics may not be available locally. By bringing together mathematicians from a wide range of specialisms at Study Groups and Modelling Weeks, this COST Action will help to connect mathematicians with their colleagues in neighbouring countries, thereby broadening the pool of expertise available for industrial problem solving. This COST Action will also provide an unrivalled recruitment opportunity as academics and industrialists get to observe, first-hand, young researchers' capabilities in, or potential for, solving real-world problems.

Reducing the costs of collaboration

In order to establish a successful collaboration, the industrialist must invest significant time, money, and effort into explaining the problem to the mathematicians. This investment can be minimised by explaining the problem to a diverse group of mathematicians in a structured environment, such as that provided by a Study Group. This COST Action will expand the use of Study Groups for this purpose.

Sharing the skills of collaboration

Members of this COST Action will be available to give advice on all aspects of working with industry. By establishing Study Groups and Modelling Weeks in more European countries, this COST Action will encourage experienced industrial mathematicians to share best practices for industrial collaboration more widely within Europe. Experienced industrial mathematicians will undertake intellectual leadership roles at these events. Knowledge of how to organise these events successfully will also be transferred.

Maintaining and strengthening collaborations

Contacts and networks

Typically, at a Study Group or workshop several methods of solution are explored, and the best way forward identified. However, action needs to be taken to maintain momentum. A report on the results from a Study Group will form the basis for further work, but the company (in particular SMEs) may not be able to commit sufficient resources to take the research to the development stage. This COST Action will promote STSMs to industrial hosts to test and validate promising ideas that may have commercial potential, providing an ideal mechanism to explore implementable solutions. This will have the added - and longer-term - benefit of giving the researcher real industrial experience, and the company a recruitment opportunity.

Once the Action is established advertisement of the activities via personal contacts the web, and through national applied mathematics societies will be launched. ECMI already has a membership that covers 23 European countries and all ECMI members will be contacted directly. EU-Maths In, a current initiative of the EMS and ECMI, plans to set up a sophisticated website for information on industrial mathematics which will contain a portal advertising jobs and events, a depository for thematic software and a directory of mathematical expertise. This will be a very useful, and complementary, asset for the members of this COST Action and will provide an ideal platform on which to promote activities.

Subject matter experts from other disciplines will be contacted on a case-by-case basis - should the need arise – for specific industry projects or workshops.

Industrial support

The development of methodologies from initial questions, through feasibility study and simulation to the pre- development stage will convince industry of the efficacy of mathematics, and increase the chance of further investment in the future. Study Groups and other industry projects should be self-financing eventually, but until the company representatives have seen that they get useful results from mathematics they are reluctant to invest much time or money. The increasing number of companies who return to Study Groups with new problems clearly indicates that once initial scepticism is overcome there is a huge appreciation of the benefits of working with professional mathematicians.

Other sources of European funding

Through this Action's activities, the process of setting up the best teams of academic (and industrial) partners for Horizon 2020 projects will be simplified. The Management Committee will also act as a point of support for researchers new to the process.

Horizon 2020 schemes such as the Marie Sklodowska-Curie Initial Training Networks (ITN) for Early-Stage Researchers, the Marie Sklodowska-Curie International and inter-sectoral Research and Innovation Staff Exchange Scheme (RISE), and the European Research Council's Synergy Grant are all very well suited to industrial mathematics. All have minimum requirements in the numbers of participating partners from different countries.

Another Marie Sklodowska-Curie grant scheme requires at least one academic partner and at least one industry partner from different countries. The European Industrial Doctorate (EID) is a PhD scholarship where young researchers split their time equally between industry and academia. This is an ideal mechanism by which projects initiated under this COST Action can be developed further.

Time, money and infrastructure

Many academics have a high teaching load during term time, and a reduced teaching load during holiday periods. A Study Group provides an excellent way for busy academics to get started on a new research problem, and many find it highly motivating to work collaboratively with industrial scientists and other mathematicians.

Some academics would like to supervise a young researcher, but do not have sufficient funding to support a 3+ year PhD project. This Action will enable effective matchmaking between academics with limited, but unused, resources of funding and supervision time, and visiting researchers.

Conference centres are very expensive to hire, but university buildings are often idle during holiday periods and due to access to library and computer facilities, as well as appropriate software, are ideal as venues for Study Groups and other workshops.

C. MILESTONES AND DELIVERABLES: CONTENTS AND TIME FRAMES STRATEGY

Objective 1 (A.5) - Type: Development of knowledge needing international coordination: new or improved theory/model/scenario/projection/simulation/narrative/methodology/technology/technique

1. Science and Technology Event or Meeting, Action Workshop.
2. Science and Technology Coordination, Application for Framework Programme Funding.
3. Science and Technology Coordination, Application for Funding to National Programs or Agencies.
4. Joint peer-reviewed publication, open access.

Objective 2 (A.10) - Type: Dissemination of research results to stakeholders (excluding specific input in view of knowledge application, as per objective 7)

1. Stakeholders Outreach, including Unwritten Inputs and Dissemination, to end users/practitioners.
2.Joint peer-reviewed publication, open access.
3. Internal and External Communication, Website.
4. Science and Technology Event or Meeting, Action Workshop.
5. Science and Technology Coordination, Short-Term Scientific Missions (STSM).

Objective 3 (B.15) - Type: Involving specific target groups (e.g. newly established research groups, Early-Stage Researchers, the under-represented gender, teams from countries/regions with less capacity in the field of the Action)

1. Achievement of Specific Network Features in terms of WG Composition, expertise.
2. Science and Technology Coordination, Short-Term Scientific Missions (STSM).
3. Internal and External Communication, Website.
4. Internal and External Communication, Virtual Network: any web-based resource needed for work coordination among Action Members.
5. Science and Technology Event or Meeting, Training School.

In this section indicative time frames for activities are provided. All proposed Objectives (A.5, A.10, B.15) are addressed, especially A.5 on international coordination. The Milestones correspond to the formal/operational aspects of the project, taking into account best practice. To promote the participation of countries with less capacity on-site industrial workshops and industrial mathematics education and training for young researchers will be organised. This tackles the two key Challenges described in Section A.

Date	Milestone
1st MC meeting	1. Management Committee (MC) established. Minimum of five members from at least five different COST countries. 2. Working Groups established. At least three COST Action members recruited to each of the following areas: • Industrial Workshops • Education & Training • Case Studies • Membership & Publicity
One month after 1st MC meeting	3. Website established by the Membership & Publicity Working Group, and populated with the following information: • Mission statement • Current members, WGs and MC. • Instructions for joining the Action

In each of the following events described there will be a local organising committee, but these will be overseen by the central Working Groups. At least one member of the central committee will help or advise with the local organisation.

C.1 Annual events

The main annual events supported by this COST Action will be Study Groups and Modelling Weeks. These two types of events will target all Objectives: Study Groups focus on intensive activities where the goal is to solve the problems presented by industry partners: mainly local industries, i.e. from the country where the workshop is held.

In this way knowledge is developed and transferred to countries with less capacity (Objectives A.5 and B.15), and results are disseminated to stakeholders such as partner industries, via the production of peer-reviewed publications, reports with the extended solutions to the problems, short-term scientific missions, joint young researcher supervision, etc. (Objective A.10)

Modelling Weeks focus on industrial mathematics training of young researchers, thus contributing directly to Objective B.15 via an efficient transfer of knowledge to young and Early-Stage Researchers, and incorporating countries with less capacity into the network of experts in industrial mathematics.

The Action will run one major annual event where all members have the opportunity to meet, discuss research results and industrial collaborations. There will be dedicated plenary and poster sessions for young and Early Stage Researchers to present work. Thus, Objectives A.10 and B.15 will be covered. This annual meeting will also be used to discuss the Action's progress and ambitions (covering Objective A.5), and, if necessary, review deliverables.

Date	Milestone
One month after 1st MC meeting (then in the same month in subsequent years)	1. Call for Expressions of Interest (EOIs) for the following events published on website by the Dissemination Manager and issued directly to all COST Action members: • Study Groups • Modelling Weeks • Conference
Two months after 1st MC meeting	2. Submitted EOIs, including planned dates and locations, received by MC.
Two and a half months after 1st MC meeting	3. Host institutions for Study Groups, Modelling Weeks, and annual conference selected by MC vote and funding allocated to local organisers. Milestones and deliverables for each approved Study Group and Modelling Week are described in sections C.4 and C.5 respectively.

C.2 Quarterly events

To encourage the mobility of young and Early-Stage Researchers (Objective B.15), and to ensure dissemination and outreach to industrial stakeholders (Objective A.10), the Action will seed fund multiple short-term scientific missions (to both academic and industrial hosts) each year. One-day

industry workshops, which often act as a useful precursor to a Study Group will also be supported. To facilitate these activities there will be four calls for proposals each year, following the management structure outlined in C.1 above, in line with best practice (Objective A.5).

Date	Milestone
15th January, April, July, and October of each year	1. Calls for the following published on website by the Dissemination Manager and issued directly to all COST Action members: • Short Term Scientific Missions (STSMs) to academic and industrial hosts • Themed one-day industrial mathematics workshops
15th February, May, August, and November of each year	2. Assessment of the following based on excellence and impact, prioritising applications from countries that have less capacity in the field of the Action: • STSM applications assessed by Education & Training WG • Themed one-day workshop applications assessed by Industrial Workshops WG
1st March, June, September, December of each year	3. Decisions released and funding allocated to local organisers. Milestones and deliverables for each approved, STSM, and themed workshop are described in sections C.6, C.7, and C.8 respectively.

C.3 Study Groups

Study Groups (SGs) provide efficient means to fulfil Objectives A.5, A.10 and B.15, via the direct involvement of industry partners (~6 per SG), the corresponding training of young and Early-Stage Researchers (~80 academics per SG), and the focalisation of industrial mathematics into countries of less capacity. The following Milestones account for organisational aspects and the Deliverables represent the outputs.

Date	Milestone
7 months before the start date of each SG:	1. Appointment of lead local organiser.

6 months before the SG:	2. Local committee, including administrative support, established. 3. Long list of companies and contacts to target compiled by the local committee. 4. Website established and populated with any confirmed industrial problems, registration details, accommodation and travel information. 5. Open call for industrial problems published on the website.
5 months before the SG:	6. Shortlist of incoming and external industrial visits compiled by the local committee. 4 months before the SG: 7. Call for academic participants issued to all COST Action members and external partners (e.g. EMS, ECMI, members' contacts). 8. Experienced SG participants (depending on problems) invited.
2 months before the SG	9. Industrial problems selected by local organising committee vote. 10. Academic registration closes.
2 weeks after the SG	11. Technical report for each industrial problem completed and submitted to industrial partner. 12. Plan for follow up activities (site visit, STSM applications etc.) developed in collaboration with each industrial partner.

Deliverables:

I. Technical report for industrial partner prepared by each group.

II. Report uploaded to The Mathematics in Industry Information Service (MIIS) repository.

III. Dissemination of research results: presentation to a wider audience on industrial partner premises.

IV. Collection of case studies to be collated in a booklet by the Case Studies WG and published on the website.

C.4 Modelling Weeks for young researchers

Modelling Weeks fulfil Objectives A.10 and B.15, via the focused training in industrial mathematics. Also, Objective A.5 is fulfilled via the transfer of knowledge from the senior experts and industrialists to the young and Early-Stage Researchers. The following Milestones account for organisational aspects and the Deliverables represent the concrete outcomes.

Date	Milestone
6 months before	1. Appointment of lead local organiser.

the start date of each workshop	2. Local committee, including administrative support, established. 5 months before workshop: 3. Workshop website established and populated with registration details, accommodation and travel information. 4. Open call for young researcher participants published on the workshop website and issued to all COST Action members and external parties (e.g. EMS, ECMI, members' contacts). Young researchers to provide statement of why they wish to attend and a reference from supervisor. 5. Long list, in order of preference, of potential local and external group instructors compiled by the local organising committee.
4 months before the workshop	6. Local instructors confirmed. 7. Invited external instructors finalised. 3.5 months before workshop: 8. Closing date for young researcher registration. 9. Local organising committee assessment of applications. Statement, reference, and good mix of participants (by location) all taken into account in the decision.
3 months before the workshop	10. Successful young researcher applicants notified.
2 months before the workshop	11. Problem statements uploaded to the workshop website.
Final day of the workshop	12. Small prize for best group presentation judged by lead organiser and local committee.
2 weeks after the workshop	13. Summary poster from each group completed. 14. Small prize for best poster judged by Education & Training WG. 1 month after workshop: 15. Oral presentation from each group member given at home institution and recorded to video and uploaded to workshop website. 16. Small prize given for best one judged by Education & Training WG.

Deliverables:

I. Collection of best posters uploaded to the COST Action website.

II. Collection of best videos uploaded to the COST Action website.

C.5 STSMs to industrial hosts

STSMs to industry (also known as Industrial internships or secondments) provide training to young researchers by giving them up to 3 months' hands-on experience and mobility in the field of industrial mathematics. They are also important for generating new, or strengthening existing, industrial collaborations.

The basic milestone in this section is a discussion between academics and industry representatives during or as a follow- up to a study group or conference. The company representative may apply to host a young researcher, who can work on extending the results or other problems relevant to the company.

Deliverables:

I. Each young researcher to prepare a one-page case study.

II. Case studies to be collated in a booklet by the Case Studies WG.

III. Case studies uploaded to the COST Action website.

C.6 Short term scientific missions to academic hosts

Short term scientific missions (STSMs), of 1 week-3 months' duration, will primarily be used to support research visits to i) complete a piece of follow up work after a Study Group, ii) prepare a joint application for funding, iii) co-author a peer- reviewed, journal publication. Both home and host institution should be in an institution in a COST country which has accepted the Action's MoU. STSMs play an important role in strengthening relationships with industry partners and streamlining collaborations.

Milestones:

1. Discussion between academics and industry partners over the most suitable type(s) of STSM for the given problem. For example, follow-up work after a Study Group, joint application preparation for funding, publication in a journal.

2. Quarterly application as per section C.3 above.

Deliverables:

I. One page summary report prepared by visiting researcher.

II. Joint peer-reviewed publication or funding proposal co-authored by visiting researcher.

III. Outputs uploaded on the website.

C.7 Themed one-day industrial mathematics workshops

These often act as a useful precursor to a Study Group. In countries with less capacity, they act as igniters by transferring knowledge to local academics from the invited speakers, who usually come from more experienced industrial mathematics groups. To stimulate engagement with local companies, industrialists who are likely to be interested in the theme (for example, granular flow, forecasting under uncertainty) will also be invited.

Deliverables:
I. One page summary report prepared by local organising committee.
II. Reports uploaded to the website.

D. ACTION STRUCTURE AND PARTICIPATION – WORKING GROUPS, MANAGEMENT, INTERNAL PROCEDURES

The Management Committee (MC) will comprise at least five members from five different COST countries, as nominated by those countries' national coordinators.
Under the MC's direction, four Working Groups (WGs) will be established in: Industrial Workshops; Education & Training; Case Studies; and Membership & Publicity. Each WG will comprise a Leader and at least three ordinary members from at least three different countries. The STSM manager will sit on the Education and Training WG, and the Dissemination manager will sit on the Case Studies WG. The WG Leader is responsible for leading the group and maintaining strong channels of communication with the MC.
Prior to the first MC meeting, the appointed MC members will request nominations for the named MC roles (detailed below) and the WG Leader, encouraging both industrial and academic nominees. At this meeting, these roles will be allocated by majority vote. Ordinary WG members will be nominated by the MC, once the WG Leaders are in place.
To ensure the Action remains lively and responsive to industry and academia's needs, the Action will be open to accept new (academic and industrial) members, MC members, and WG members, at any time.

D.1 Management Committee

The primary collective responsibility of the MC is to evaluate, and approve or reject, applications for financial support for the Action's core activities, according to the milestone process described in section C. These include proposals for Study Groups (SGs), STSMs, Modelling Weeks, and associated expenses. Deliverables resulting from these activities, such as technical reports, will also be approved by the MC before being made publicly available.

Named MC roles:
Chair: Responsible for leading the Action strategy, and producing an annual report of the Action's activities and outputs. Vice-Chair: Responsible for reviewing the Action strategy, and assisting the Chair in producing the annual report. Grant Holder: Responsible for overseeing the Action budget and the annual financial report. The Grant Holder will provide current financial information as required to support the decision-making of the MC.
MC meetings will be held twice a year. At one of these meetings, based on the budget and informed by the previous year's financial report (if applicable), the MC will decide how many events it can support. As detailed in section C, a call for proposals will be sent out and the MC will decide on host locations for these events by majority vote. Countries and institutions that have not run these events before will be prioritised.
The Grant Holder administrative representative will also attend each MC meeting, and be responsible for taking minutes and ensuring follow up on action items.

D.2 Industrial Workshops WG

The members of this WG will primarily be experienced organisers of, or industrial participators in, SGs or similar workshops. This WG will be responsible for issuing calls for proposals for SGs and themed workshops according to the milestone process described in section C, and submitting received proposals to the MC for assessment.
For each workshop assisted by this Action, the WG Leader will assign one WG member to oversee planning and organisational structures, and two further WG members to act as advisors to the workshop's local organisation committee. This advice will include help with advertising, establishing industrial contacts, selecting suitable problems, inviting experienced participants, and planning follow-up activities.

D.3 Education & Training WG

This WG will be responsible for issuing calls for proposals for Modelling Weeks and STSMs, according to the milestone process described in section C. Received proposals will be submitted to the MC for assessment.
For each Modelling Week assisted by this Action, the WG Leader will appoint one member of this WG to oversee the activity. These oversight duties will include helping the local organisers to advertise widely and recruit young researchers fairly, ensuring a diverse range of international participants. The WG Leader will assign one WG member to act as a point of contact for each STSM supported by this Action.

Finally, this WG will advertise and offer support for researchers to attend events organised by the Industrial Workshops WG.

D.4 Case Studies WG

The objective of the Case Studies WG is to maximise the quality of the deliverables 4.I, 4.IV, and 6.II described in section C. For each Study Group and STSM to industry supported by this Action, the WG Leader will appoint one member of this WG to act as editor of his or her case study. The editor will be responsible for providing advice on issues such as publication venues and company confidentiality, and publishing reports on the Action website.

D.5 Membership & Publicity WG

This WG will be responsible for establishing and maintaining the Action website, through which most of the Action's publicity activities will be directed. The website will list Action members, MC members, WG members, scheduled events, contact points for current activities, and open calls for proposals. Updates will be made according to the milestone processes in section C, and with the Administrator's assistance.
A key task of this WG will be to promote this Action to all sectors of industry, especially SMEs. This WG will exploit all available contact networks to recruit more members to this Action, with particular emphasis on countries that currently have little activity in industrial mathematics. This can be done as explained in Section B3.1 but also by advertising via the national applied mathematics societies

and by writing articles in publications such as the EMS Newsletter (published quarterly and sent to over 3000 mathematicians across Europe).