



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

Brussels, 15 May 2014

COST 044/14

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action IC1404: Multi-Paradigm Modelling for Cyber-Physical Systems (MPM4CPS)

Delegations will find attached the Memorandum of Understanding for COST Action IC1404 as approved by the COST Committee of Senior Officials (CSO) at its 190th meeting on 14 May 2014.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as
COST Action IC1404
MULTI-PARADIGM MODELLING FOR CYBER-PHYSICAL SYSTEMS (MPM4CPS)

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 COST 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 enhance the quality, visibility and impact of European research and industrial adoption in the trans-disciplinary area of Cyber-Physical Systems (CPS) by unification through Multi-Paradigm Modelling.
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 76 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.

A. ABSTRACT AND KEYWORDS

Truly complex, designed systems, known as Cyber Physical Systems (CPS), are emerging that integrate physical, software, and network aspects. To date, no unifying theory nor systematic design methods, techniques and tools exist for such systems. Individual (mechanical, electrical, network or software) engineering disciplines only offer partial solutions.

Multi-paradigm Modelling (MPM) proposes to model every part and aspect of a system explicitly, at the most appropriate level(s) of abstraction, using the most appropriate modelling formalism(s). Modelling languages' engineering, including model transformation, and the study of their semantics, are used to realize MPM. MPM is seen as an effective answer to the challenges of designing CPS.

The Action aims to promote the sharing of foundations, techniques, and tools and to provide educational resources, to both academia and industry. This will be achieved by bringing together and disseminating knowledge and experiments on CPS problems and MPM solutions.

Keywords: Cyber-Physical Systems (CPS), Complex Systems Development, Multi-paradigm Modelling (MPM), Model-Based Systems Engineering (MBSE), (co-)Simulation, Control Systems, Control Theory, Embedded Systems, Systems-of-Systems, Mechatronics, Networks, Distributed Systems, Software-Intensive Systems.

B. BACKGROUND

B.1 General background

In virtually any area of human activity, truly complex, designed systems, known as Cyber Physical Systems (CPS), are emerging. These multi-disciplinary systems deeply integrate collaborating physical, software, and network parts.

Tackling the complexity involved in developing software intensive and embedded systems (SiS/ES) is a topic of intense research and development. The complexity faced when engineering CPS is however several orders of magnitude higher, mostly due to the plethora of cross-disciplinary design alternatives and inter-domain interactions. The solutions for SiS/ES challenges that the systems and software engineering communities have come up with (e.g., multi-resolution modelling of physical systems, computationally a-causal modelling of multi-physics systems, aspectual multi-view modularization) are simply no match for the complexity observed in CPS. As a consequence, to date, no unifying theory nor systematic design methods, techniques or tools exist for CPS.

Individual (mechanical, electrical, software) engineering disciplines (in the form of theories, methods and tools) only offer partial solutions.

The foundational infrastructure that is able to glue together in a consistent way the several disciplines of CPS is Multi-Paradigm Modelling (MPM). MPM is a research field focused on breaking the inherent complexity of large-scale and complex systems into different levels of abstraction and views (i.e., rigorous models of some physical or logical reality), each expressed in appropriate modelling formalisms. By appropriate, not only cognitive aspects (which impacts learnability and usability of the used formalism) are understood, but also technical ones such as tractability for debugging and analysis.

Modelling language engineering (using model transformations), and the study of their formal semantics, is used to realize MPM, by combining multiple models of computation such as continuous-time, discrete-event, and synchronous data flow. MPM, viewed as the logical continuation of Model-Based Systems Engineering (MBSE) and Model-Driven Engineering (MDE), is becoming a successful approach by providing processes as well as software tools that are able to combine, couple, and integrate each of the views that compose a system.

The main goals are to analyse (for safety and reliability), to simulate (for optimization purposes) and, where appropriate, synthesize these systems.

Research activities focusing on Modelling of CPS are typically based on national activities and generally lack a concerted approach at European level. A dedicated interdisciplinary and inter-institutional platform for scientific information exchange, consensus building, and model improvement is thus required. COST provides the best available mechanism for broad European networking and capability-building. A COST Action is the most appropriate framework since only in a non-competitive, interdisciplinary environment it will be possible to identify and verbalize the weaknesses and uncertainties related to CPS modelling approaches, to develop common strategies for improving the performance of such tools and to develop and broaden the available research expertise.

The intended COST Action will involve, support and harmonize the various existing national activities around CPS modelling, and will benefit from the results of previous COST Actions, such as IC0901 and IC285. One innovative aspect of the Action is the effort of bringing together scientists and experts in Mechatronics, Smart-Cities, CPS, Software Modelling and Engineering, and Multi-Paradigm Modelling, in order to push development and implementation of state-of-the-art scientifically justified methodologies of CPS modelling in several application domains such as automotive and avionics. In order to ensure a direct impact of the scientific output, the Action is characterized by a high level of specialization and is aiming at a well defined target. Based on the

joint expertise and contacts with international programmes, the Action will harmonize with the most recent developments in the USA and Canada and indeed world-wide.

B.2 Current state of knowledge

Cyber-physical systems (CPS) enable the physical world to merge with the virtual, leading to an Internet of Things, data and services. One example of CPS is an intelligent manufacturing line, where the machine can perform many work processes by communicating with the components. Using sensors, the embedded systems monitor and collect data from physical processes, such as steering of a vehicle, energy consumption or human health functions. The systems are networked, making the data globally available. Cyber-physical systems make it possible for software applications to directly interact with events in the physical world, for example to measure and react to changes in blood pressure or peaks in energy consumption.

The problems related to CPS were identified in several application areas – from automotive to avionics – all around Europe, and therefore are certainly international. However, each application (at a national level) is developing different techniques – from mechatronics to embedded systems – lacking the ability to systematically share and reuse any of the acquired techniques and lessons learned among them.

Entire conferences, initially conceived in the US, but now increasingly in Europe, on the topic of CPS exist and have led to a vast body of published work. A pertinent example is the CPS week, held in Berlin this year, which groups 5 conferences, 10 workshops and 4 tutorials. Similarly, MPM, as a part of the Model-Driven Engineering and Model-Based Systems Engineering community also has a very active community. The combination of both communities will lead to the much-needed breakthroughs in unified (i.e., not rooted in specific application domains or solution techniques) dealing with complexity.

The need for a tighter integration of research – both with respect to the technological and the application domains – to ensure the competitiveness of the European industry has already been recognized on the strategic level of Horizon2020. A stronger cooperation in ARTEMIS, Eniac, and EPoSS as core technology domains of CPS is a clear indicator for this as well as the targeting of cross-domain issues such as smart energy and traffic. However, currently many of the research projects established in this field have a limited focus, addressing only few domains and their models needed to solve a specific problem (e.g., e-mobility for cars in POLLUX). Those few integration projects with a broader scope of models – like iFEST or CEASAR – limit their scope to tool coupling, but much less on an integration of modelling paradigms of different domains. On the

national level, research agendas such as the German agenda CPS sponsored by the BMBF, have expressed the need for a cross-domain systems theory, integration the models for the individual domains. First research projects – like within the German Industrie 4.0 framework – addressed this need for specific domains like production and automotive. Here, this COST Action provides the necessary framework for connecting and extending these projects, establishing the necessary inter-domain understanding to enable the innovation potential of CPS.

B.3 Reasons for the Action

It is timely to introduce the Action since many related national research activities are under way. Information about state-of-the-art embedded systems, mechatronics for avionics, mechatronics for automotive, etc., is already exchanged among European countries, mostly via independent application-specific industrial standards. There is a clear need to bring different solutions from different technology and application domains together around CPS. The MPM perspective which advocates modelling every part and aspect of a problem explicitly, using the most appropriate formalisms and abstractions, with explicitly modelled processes, is seen as the main enabler. We wish to guide the further development and dissemination of MPM and CPS at the European level. This task can, however, be extremely difficult to complete without a strong large-scale collaboration, mostly due to a non-obvious convergence of proper problem and solution models (and their techniques) and due to the multiplication of efforts in the distributed groups. The Action is needed now, because ongoing research will benefit immediately in the context of the conceptual and application-oriented improvements achieved by the Action. The dissemination of the scientific results and the best practice recommendations produced by the Action, through publications and special sessions at conferences and workshops, will have an immediate impact on applied CPS modelling and CPS industrial development.

The present COST action aims at creating the conditions necessary for promoting the sharing of resources, by integrating, under a common umbrella (i.e., in a consistent and systematic way with a common terminology), the knowledge and experiments across several research projects around Europe (and beyond). In addition, this COST action provides a unique opportunity to establish international cooperation, and to exchange materials (data, models, insights) and compare results. Finally, this Action is expected to have an important impact on European policy with respect to regulations of the methodologies and procedures to develop and certify this kind of systems, combining national and international legislation. Also, better dissemination and collaboration will contribute to harmonising these procedures among EU member states. In this way, transfer to the

international level would be highly beneficial for the internationalisation of CPS within the EU Industry. Here is a unique opportunity to determine appropriate ways of dealing with CPS in different industrial environments.

B.4 Complementarity with other research programmes

This Action focuses on MPM for CPS, and these aspects combined are not covered by other COST Actions or EU-projects. As the Action necessarily has to include many aspects of CPS (e.g., mechatronics in several application domains, etc.), there will be links with other research programmes as indicated:

a) Links and complementarity with (the results of) other COST Actions: IC0901 - Rich-Model Toolkit - An Infrastructure for Reliable Computer and IC285 - Modelling and Simulation Tools for Research in Emerging Multiservice Telecommunications

b) Links with other EU research programmes:

- ‘Cyber Physical Systems European Roadmap and Strategy’ (CyPhERS). FP7 project.
- CPS Action Line “Cypher Physical Systems” of the EIT ICT KIC.
- ‘Industrial Framework for Embedded Systems Tools’ (iFEST).
- ‘Combined Model-based Analysis and Testing of Embedded Systems’ (MBAT).

C. OBJECTIVES AND BENEFITS

C.1 Aim

The main objective of this Action is to enhance the quality, visibility and impact of European research and industrial adoption in the trans-disciplinary area of CPS. This goal is pursued by building a network of researchers, educators, industrial practitioners and policy makers in order to establish the foundations and methods of CPS Engineering enabled by MPM. This will allow coordinating and shaping the efforts on research, education and application in this emerging research field.

C.2 Objectives

Secondary objectives:

- To 1) develop hypotheses based on exchange of results from national research and development, 2) coordinate proposing benchmark experiments in each application domain, and 3) disseminate information and results within several areas.
- To apply the MPM approach by developing common acceptance for combinations of different models, modelling languages, simulation and verification tools and assert their applicability in the Industry.
- To evaluate the interdisciplinary know-how required from a software/system's engineer in order to develop and maintain such kind of systems at the European scale, and if necessary develop new course materials in order to cope with such needs.
- To develop research-based guidelines for evaluating and characterizing cyber-physical systems.
- To evaluate software engineers' practice and system engineers' methods and thereby establish an approach to engineer and maintain these systems.

C.3 How networking within the Action will yield the objectives?

The following, concrete instruments will be employed to pursue the Action's objectives:

- Organize regular coordination meetings (at least two per year, following each MC meeting) giving particular emphasis to technical discussions and presentations; representatives from EU projects and externals experts will be regularly invited to participate in the technical discussion;
- Organize a series of yearly workshops and symposia, while inviting key speakers, lecturers on software modelling and MPM, as well as CPS experts, from both academy and industry. These events will widen the information input and foster the immediate dissemination of results produced by the Action;
- Produce a series of Annual Reports surveying the state-of-art on MPM for CPS and reporting case studies on the adoption of CPS technology in real-world, complex applications;
- Organize yearly Summer Schools for young researchers;
- Organize Short Term Scientific Missions (STSM) for junior and senior participants;
- A website will be established for efficient information exchange between the members of the Action, and dissemination of results with the public. This implies an efficient setup of a portal and associated electronic collaborations tools (thematic discussion forums and mailing lists).

C.4 Potential impact of the Action

- Formation of a dedicated trans-disciplinary, cross-national pool of information exchange intended

to last far beyond the lifetime of the Action;

- Increased quality and level of inter-disciplinarity of MPM for CPS (MPM4CPS) research;
- Reducing fragmentation of research through the definition of a common research agenda on MPM for CPS, and by bringing together experts from both research and industry (MPM4CPS community building);
- Promoting MPM and CPS education by defining the MPM4CPS discipline, while identifying: the required profile for CPS expertise, and the core of topics, competences and specialities in MPM4CPS education;
- Synergy between industrial partners from different application domains around CPS (expected economical benefits for the European region and leadership establishment of the European institutions in the MPM4CPS area - namely by means of patents and standards);
- Enhanced competitiveness of European ICT industry by: 1) fostering the adoption of the MPM4CPS practices and methodologies, capable of boosting the productivity of the development process of existing and new complex application domains; and 2) creating new markets for CPS tooling (hence also the presence of tool builder industrial partners of this Action).

C.5 Target groups/end users

The Action will provide a forum for exchange of knowledge and expertise between system engineers, software engineers, and researchers from different areas: simulation, mechatronics, embedded systems, networks, distributed systems, systems of systems, and software modelling.

System Engineers:

- Definition of appropriate modeling, monitoring and control tools for cyber-physical systems.

Cyber-physical systems testing authorities:

- Recommendations for new testing and listing procedures for testing Cyber-physical systems
- Procedures for combining existing information (e.g., weather, social information) in order to simulate and test Cyber-physical systems.

Software Engineers and Software Industry:

- An established MPM4CPS discipline: a roadmap for high quality MPM4CPS education in Europe.
- Increased productivity in developing a Cyber-physical system as a whole.
- Increased stability and quality of the developed Cyber-physical systems.

- Heterogeneity: New strategies for exploitation on different computation platforms.

Researchers:

- A European Network supporting researcher mobility to ensure interaction on planning of experiments and on analyses of results as well as publication of common papers.
- A European Network within which applications for European project funding can be generated.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

This Action will focus on both syntax and semantics principles of modelling language engineering. The scientific innovation in this Action will mainly result from the combination of research activities that focus on these particular scientific topics.

Syntax: Currently the design of a CPS solution is made from scratch using dedicated tools which are rather specialized to a particular application domain (e.g., automotive CAD) or technique (e.g., FPGA EDA tools for embedded systems). Their lack of interoperability features brings enormous problems, both conceptually and from a tooling point of view, when trying to combine different techniques and/or application domains. The Action will develop an unified framework/language for facilitating a sound integration of such kind of CPS methods, techniques and tools (both existing and new). The existence of ontologies, including behavioural descriptions, for CPS will partly help this development. The main scientific contributions of the Action in this topic will be the conceptualization of techniques and tools for improving interoperability, new ontologies and formalisms (and the link between them) to deal with the heterogeneity and perform the integration of the problems resulting from several application domains, under a common MPM4CPS umbrella.

Semantics: The major weakness of current system's analysis, is both the completeness and soundness of the analysis. The Action envisions to exploit the semantically rich MPM4CPS framework to dynamically instrument and compose existing analysis tools (e.g., generic symbolic model checkers, co-simulators), in order to reach valid and pertinent conclusions about the CPS under analysis in an economically realistic time. The main scientific contributions of the Action in this topic are the conceptualization of dynamic search heuristics for instrumenting and composing together analysis tools designed for simulation and co-simulation, design-space exploration, model checking and verification of safety properties, and efficiency/optimization, that are currently being used in the context of both CPS development and certification.

The major tasks in this Action are:

- 1) To review the current suite of methods, techniques, tools and models that are currently used in practice while building and developing complex Cyber-Physical Systems.
- 2) To identify deficiencies in the used tools and underlying modelling languages that limit their effectiveness, usability and operational use in developing and maintaining complex CPS.
- 3) To determine the minimal required information for a CPS language, in order to glue CPS descriptions expressed in multiple formalisms and deployed in multiple and distinct application domains.

The Action is arranged to address these three tasks in a comprehensive and scientific way. Both developers and users of CPS have a mutual interest in increasing the performance, usability, interoperability and reliability of tools applied for building CPS. In order to classify current CPS development activities and extrapolate a rather general foundational framework around CPS development, a detailed study of the current suite of tools is needed. Hence, one of the first scientific deliverables of the Action will be a modeling-oriented characterization (report) of CPS tools and formalisms currently used in the different CPS application domains (e.g. industrial scenarios, etc.).

A second task to be coordinated and worked on by the Action is the setup of a dedicated comprehensive inventory of CPS models that are applicable to several different application domains such as the industrial automotive and avionics scenarios. In many cases, National and/or institutional inventories have been compiled but a complete and consistent European catalogue of tools and modelling languages is not yet available. Considering the variety of models, modelling languages and tools to be listed now and in the future, it will be a task of the Action to start the initial design of a flexibly structured CPS model repository (inspired by the REMODD initiative in the US). This will enable efficient and unambiguous access to the information on a given CPS, such as physical background, computational demands and information on model verification or related performance measures.

A key task of the Action is to identify the main gaps, deficiencies and limitations in presently available CPS development tools and their underlying modelling languages, and to determine the directions for the development of the next generation of CPS modelling languages and supporting tools (based on MPM principles). Future CPS modelling tools will not be just improving the integration and interoperability between the different CPS disciplines, but fundamentally they will provide better performance in the tasks of analysing, understanding, simulating and maintaining a CPS under development. Formalisms such as Modelica are still found inadequate to fully address these tasks in what matters to usability and computational power.

A further scientific task to be addressed by the Action is the integration of current modelling,

simulation and verification tools that can be seamlessly used on the case of CPS. In this context it is important to consider not only the tools made for software, but also for electronic and embedded devices, and continuous control systems as well. With the fast-changing application domains and eager for new technology (like the automotive), it is of special importance to consider the definition and documentation of commonly accepted CPS modelling languages. Collecting and integrating as much as possible information from outside of the Action for example by organizing workshops as mentioned in Section C will enable the information input to the Action to be maximized.

D.2 Scientific work plan methods and means

In this section the WG aims and activities are described. Further information on WGs can also be found in section E.2.

WG 0: Cross-WG Activities, Showcases

WG0 plays a special role within this Action by bundling cross-WG activities in order to ensure their cohesion, boost interdisciplinary collaborations, while avoiding the natural clustering (e.g., the creation of micro-communities per workgroup) within the large network formed by this Action. Specifically, this WG will be in charge of the integration of the remaining four WGs so that researchers in these different fields can share their common expertise, favouring cross-fertilization and minimizing fragmentation and duplication of research and efforts. Exchanges between the WGs will be promoted, also by financially supporting inter-WG visits.

Furthermore, this WG will oversee tasks related to dissemination towards end users, including the design and development of the showcases of the Action.

WG 1: Foundations - Intra and inter-Disciplinary Interaction

The objectives of WG1 is to apply and mostly combine MPM, Control, Hybrid Systems, ... techniques while dealing with the heterogeneity of CPS, and identifying common formalisms, and ontologies used in CPS development. WG1 will characterize/categorize existing modelling languages on the different disciplines using typical industrial CPS scenarios. WG1 will compile, evaluate, possibly complete and document existing modelling tools for CPS modelling. Specific research questions asked and tasks to be performed will include:

- What are the currently CPS methodologies and what is the current state-of-the-art in CPS modelling and development?
- Which kind of CPS tools and formalisms/disciplines are currently under development and

favoured for future application?

- What is the current generic modus-operandi of a typical industrial CPS developer.
- Define a standard terminology (Domain Ontology) for CPS.

The deliverables of WG1 will be based on previous and ongoing research work, and will include a state-of-the-art report on current formalisms used on CPS development. This report will include: 1) a structured catalogue of tools and modelling languages; and 2) a glossary of terms to be used throughout CPS modeling language's development, evaluation and application.

WG 2: Techniques

The objective of WG2 is to conceptualize usable and efficient MPM integrated environments for CPS development, while increasing CPS development's productivity (e.g., by means of increased interoperability, and use of visual modelling languages) and reducing the complexity of CPS testing, simulation and certification procedures. Secondary objectives of WG2 is to investigate CPS Standards that can be used by Europeans regulators in order to increase performance, security and safety of industrial CPS in Europe, and worldwide.

Specific problems to be solved by WG2 are:

- Which kind of MPM modelling tools are currently under development (e.g., software engineering, embedded systems, complex control systems, etc.) and favoured for future application in CPS?
- Developing tools, standards and best practices that can be virtually integrated in a conceptual MPM environment.
- Demonstrating and evaluating the increase of efficiency of such modelling environments on CPS (i.e., not only in what matters to development speed, but also on certification speed).

Accordingly, the deliverables of WG2 will include: 1) a report of standards and best practices in MPM modelling on CPS; 2) a state of the art on MPM modelling tools used in different disciplines; 3) a report containing considerations for future MPM modelling tools; and 4) an efficiency evaluation of MPM modelling tools on CPS (e.g., versus non-modelling approaches of CPS development and certification, etc.).

WG 3: Application Domains

WG3 will focus on the practical constraints in the use of MPM modeling in two representative and distinct CPS application domains: 1) embedded systems, control systems where CPS has emerged from (e.g., automotive, aerospace); 2) or more networked, unanticipated changes (both structure

and behaviour) and less of the traditional plant/controller architecture, which may have emergent behaviour (e.g., smart-cities, complex traffic management). The specific needs of the industry in these domains have to be taken into account in order to successfully implement the scientific improvements gained by the Action. WG3 will work together with industrial partners to ensure a bilateral feedback between the scientific and industrial CPS communities. The main tasks covered in WG3 are:

- Definition of Benchmark Case Studies.
- To access the current state of CPS and CPS modeling at a national level.
- To collect the requests and requirements of each application domain, and rewrite them into a CPS perspective.
- To assess the suitability of the different application domain models while being expressed in CPS perspective (e.g., completeness, usability, interoperability with existing tools, etc.).
- To give recommendations on the proper use of different models and methodologies and the reliable assimilation of current application domain models in the perspective of CPS modeling.

Guidance and training documents will be produced. The Action's intention is not only to evolve scientific contents, but also to provide immediate practical prototype tools. This will be emphasized by delivering and publishing:

- A documentation of recommended procedures for the use of CPS models in the context of several application domains.
- Information on what type of model(s) or approach (es) to be used for which type of scenario.
- Practical guidance for the optimum use of CPS models or MPM modelling approaches required to improve the quality and efficiency on each application domain.
- Report of the current state of the art of CPS and CPS modeling at a national level.

In the last year of the Action, a summarizing report will be finalized, peer-reviewed and published. It will be the task of the members of the Management Committee (MC) throughout the entire Action to actively promote the techniques, tools, strategies and standards developed by the Action. The commonly accepted application recommendations for specific application domain models and CPS modelling strategies will put pressure on model developers to carry out and document a commonly accepted CPS development and quality assurance procedure/process and to improve modeling capabilities, not solely driven by commercial interests. The Action is expected not only to improve the quality and efficiency of CPS development in a large scope of application domains, but also to develop the 'culture' of using such tools for example by a scientifically justified selection of

proper tools for a specific release scenario.

WG 4: CPS Education and Dissemination

The WG4 will focus on the crystallization of MPM4CPS contents into a suitable format for educational purposes. The specific tasks covered in WG 4 are:

- to Identify the adequate profile(s) of CPS experts (i.e., the minimum required knowledge);
- to Identify existing courses in the realm of CPS and MPM4CPS in Europe, and the need for new courses on topics relevant to CPS not yet covered by the European Universities;
- set the base for an European Master/Phd Program in MPM4CPS involving several European leading Universities and set up the respective discipline roadmap;
- promote Literature on the topic (books, articles), while defining course material (online, etc);
- promote thematic Summer Schools on MPM4CPS for researchers;
- make young students (future researchers and practitioners) aware of an enthusiastic about the topic of CPS in events such as a “CPS Hacker School”;

E. ORGANISATION

E.1 Coordination and organisation

The Action is planned to last 4 years and is operated with a organizational structure in full accordance with COST guidelines.

The activities within the Action will be co-ordinated by the Management Committee (MC). The MC will elect 5 Working Groups (WGs; detailed in Section E.2) and approve the Leader and Co-Leader of each. Each participating country will have up to two representatives on the MC.

Wherever possible, gender representation and representation from Western and Eastern European countries will be balanced on the MC; and gender representation, representation from Western and Eastern European countries, and Early Stage Researchers (ESR) status on the WGs.

A Core Group (CG) will consist of the Chair and a Vice-Chair of the MC and the Leaders of each WGs. The CG will meet for one day preceding the two biannual (one-and-a-half day) meetings of the MC.

The CG and ultimately the Chair will have responsibility for ensuring that the Action is schedule and that specified objectives are met.

Where appropriate, and within the COST funding rules, the MC and WGs will consider inviting guest lecturers/advisors to a meeting of the MC, WGs, Summer Schools or conference at Year 4.

During the first meeting of the Management Committee the implementation of tasks described in the Memorandum of Understanding will be particularized, complemented and finally agreed on. The Working Group Chairs, Vice-Chairs and Rapporteurs will be elected and the participants will be requested to specify their contribution and goals by an Expression of Commitment.

As a first milestone, within the first six months of the Action a dedicated website will be established to provide access to the Action's results, promotion and products. In particular, news about activities/events promoted by the Action, research papers, technical reports, educational material, will be published on this website as soon as they are available and released by the Action.

In order to facilitate information exchange within the Action and with other experts from outside the Action, a workgroup list (email list, ...) will be established and maintained.

The next milestone of the Action will be the first workshop/symposium after the first year of the Action, focusing on the state-of-the-art report on MPM for CPS in Europe.

In order to intensify the dissemination of the results of the Action, the annual symposia will be accompanied by Training Schools/Summer Schools on MPM for CPS subtopics. These events will be the opportunity for Working Groups to present the results of their work, involving lecturers from all three participating communities.

The intention is to familiarize both junior and senior researchers and qualified users with the new concepts and improving their practical implementation as they are developed by the Action.

The Training Schools will provide an ideal platform for establishing dedicated think tanks, formed by young scientists.

In order to maximize the efficiency of work, and minimize the costs for travelling, it is intended to combine MC meetings with joint Working Group meetings.

Governance:

The Management Committee (MC) consists of up to two representatives of each COST Country having accepted the MoU of the Action. MC Members are nominated by the COST National Coordinators (CNC) of the COST Countries they represent. The Action MC decides upon all budget-related questions, devises the general Action strategy and manages the organisation of the Action's scientific and technological activities.

Frequency: yearly in-person meeting, co-located with yearly workshop; on-demand teleconference meetings

The Core Group (CG) consists of the Chair and a Vice-Chair of the MC and the Leaders of each

WGs.

Objectives: Quality Control: CG and ultimately the Chair will ensure that the Action is on schedule and that specified WG objectives are met.

Activities: (teleconference) meetings to assess and take action when needed, meet in-person at MC meeting

Frequency: frequent (once per month)

Deliverables: reports to MC

The Industry Advisory Board is highly relevant, but covered by the large industry participation in this Action External Experts will be invited to selected workshops and CG/MC/WG meetings

The Editorial Board

Description: During the production of the State-of-Art report, Final Report and Promotional Material (such as a leaflet), an Editorial Board, nominated by MC, will coordinate the work and collect the necessary information from the Working Group members.

Objectives: Preparing documents for Dissemination

Activities: support to WG leaders and MC

Frequency: when needed (depends on frequency of reports etc.)

Deliverables: Newsletter. Leaflet. State-of-Art. Reports.

The STSM Selection Committee

Description: Very high priority will be given to Short Term Scientific Missions (STSM) to foster personal contacts between researchers and diverse communities .Highest priority will be given to Early-Stage Researchers (ESR) and female applicants. The STSM Evaluation Committee is nominated by the MC. I will assess the impact of the scientific visits and their output. Calls for proposals will be regularly (twice per year) planned. The CG decides on allocation.

Objectives: Selection of applicants for Short-Term Scientific Missions (STSM).

Activities: Selection of the STSM applicants from the action and reporting to CG/MC. Frequency: when needed (twice per year)

Deliverables: To select STSM applicants

The Training/Summer Schools Committee

Description: Training/Summer Schools will take, when possible, be organized co-located with the workshops organized by the COST Action. The challenges, concepts, methods, techniques and tools

of MPM4CPS will be taught. The intended audience are PhD students and early-stage researchers (ESR)(including from industry),.

Objectives: Organization Training Schools and their programme.

Activities: Prepare Program of Training Summer Schools (Lecturers, Trainees, Place, Venue, Location, etc.) and reporting to the MC.

Frequency: when Training/Summer Schools are organized (once per year)

Deliverables: four Training/Summer Schools (one per year)

The Gender Balance Committee

Description: the technological and scientific sector is male-dominated. A balanced participation of women and men will be sought.

Objectives: Definition and promotion of gender balance in all parts of the Action's operation

Activities: Prepare a Plan to promote involvement of Women; active outreach (such as talks)

Frequency: continuous activity; in-person meeting once per year

Deliverables: To increase female participation rate in the COST Action through new inclusions

E.2 Working Groups

Each WG will have a coordinator/chair vice-coordinator and a 'Rapporteur'. The 'Rapporteur' is responsible for collecting results within the WG, presenting them during joint wrap-up meetings promoted by WG0 and ensuring all valuable results to be included in reports.

When organizing the Working Groups it will be intentionally avoided to separate and cluster participants in each of the 4 groups (1 to 4). In fact, it will be promoted and encouraged a direct interaction of all four interrelated communities involved in the topic by nominating representatives to be part of WG 0 whose mission is to bundle cross-WG activities in order to ensure their cohesion and boost interdisciplinary collaborations.

WG 0: Cross-WG Activities, Showcases

Objectives:

- Bundle cross-WG activities in order to ensure their cohesion, boost inter-disciplinary collaborations, while avoiding the natural clustering (e.g., the creation of micro-communities per workgroup) within the large network formed by the Action

Activities:

- Monitor possible duplication of efforts across WGs
- Be a conduit for passing information between WGs
- Encourage and sponsor inter-WG visits and presentations

Deliverables:

- Report of activities (define and measure success of cross-WG activities) (yearly)
- Showcases (Y3 - Y4)

WG 1: Foundations - Intra and Inter-Disciplinary Interaction

Objectives:

- Develop MPM foundations for CPS

Activities:

- Characterize/categorize (“chart”) existing modelling languages used in the different disciplines using typical industrial CPS scenarios (see also WG 4)
- Develop MPM framework to relate/combine (unify) modelling languages and techniques
- Apply and mostly combine MPM, Control, Hybrid Systems, ... while dealing with the heterogeneity of CPS, and identifying common formalisms and ontologies used in CPS

Deliverables:

- Report. State-of-the-art report on current formalisms used in CPS development:
 - 1) a structured catalogue of tools and modelling languages (Y1, updated yearly)
 - 2) a glossary of terms (domain ontology) to be used throughout CPS (Y2, update yearly)
- Report (yearly). Framework to relate/combine modelling languages and techniques

WG 2: Techniques

Objectives:

- Conceptualize usable and efficient MPM integrated environments for CPS development while increasing CPS development’s productivity (e.g., by means of increased interoperability, and use of visual modelling languages) and reducing the complexity of CPS testing, simulation and certification procedures. Secondary objective: CPS

standards that can be used by Europeans regulators in order to increase performance, security and safety of industrial CPS in Europe, and worldwide.

Activities:

- Investigate current standards and best practices (modelling languages, interfaces for interoperability, processes, ...) used in CPS
- Survey state-of-the art on MPM tools and techniques used in different disciplines for CPS development including an efficiency evaluation of MPM tools and techniques on CPS
- Investigate requirements for future MPM4CPS modelling tools and techniques

Deliverables:

- Reports:
 - 1) current standards and best practices used in CPS, suggest where new standards might be beneficial (Y1, updated yearly)
 - 2) state-of-the art on MPM tools and techniques used in different disciplines for CPS development including an efficiency evaluation of MPM tools and techniques on CPS (Y3)
 - 3) suggestions for future MPM4CPS modelling tools and techniques (Y4)

WG 3: Application Domains

Objectives:

- Investigate practical constraints in the use of MPM modeling in two representative and distinct CPS application domains: 1) embedded systems, control systems, mechatronics, ... where CPS has emerged from (e.g., automotive, aerospace) 2) more networked, unanticipated changes (both structure and behaviour) and less of the traditional plant/controller architecture, which may have emergent behaviour (e.g., smart-cities, complex traffic management).
- The specific needs of the industry in these domains have to be taken into account in order to successfully implement the scientific improvements gained by the Action. WG3 will work together with industrial partners to ensure a bilateral feedback between the scientific and industrial CPS communities.

Activities:

- Definition of Benchmark Case Studies
- Assess the current industrial state of CPS and CPS modelling at a national level

- Collect the requests and requirements of each application domain, and rewrite them from a CPS perspective, look for commonalities/differences.
- Assess the suitability of the different application domain models from a CPS perspective (e.g., completeness, usability, interoperability with existing tools, etc.)
- Compile recommendations on the proper use of different models and methodologies and the reliable assimilation of current application domain models in the perspective of CPS modeling.

Deliverables:

- Benchmark Case Studies (Y1 preliminary, Y3 fully developed)
- Reports:
 - 1) current industrial state of CPS (Y2)
 - 2) requirements of each application domain (Y2)
 - 3) suitability of the different application domain models from a CPS perspective (Y3)
 - 4) recommendations on the proper use of different models and methodologies (Y4)

WG 4 : CPS Education and Dissemination

Objectives:

- Bring MPM4CPS contents (from WGs 1 – 3) into a suitable format for educational and dissemination purposes. Targets: academia (students, young/senior researchers), industry, commission

Activities:

- Identify the adequate profile(s) of CPS experts (i.e., the minimum required knowledge)
- Identify existing courses in the realm of CPS and MPM4CPS in Europe, and the need for new courses on topics relevant to CPS not yet covered by the European Universities
- Lay basis for an European Master/Phd Program in MPM4CPS involving several European leading Universities (and companies) and set up the respective discipline roadmap
- Promote literature on the topic (books, articles), while defining course material (online, etc)
- Promote and organize thematic Training/Summer Schools on MPM4CPS

- Make young students (future researchers and practitioners) aware of and enthusiastic about the topic of CPS in events such as a “CPS Hacker School”

Deliverables:

- Reports1
 - 1) profile of CPS expert (Y1)
 - 2) list of existing MPM4CPS courses, description of needs (Y1, updated yearly)
 - 3) plan for European Master/Phd Program in MPM4CPS (Y1-Y4)4) annotated bibliography, annotated who's who, WG reports, (non-)technical publications (Y2, updated yearly)
- MPM4CPS workshop (yearly)
- MPM4CPS poster, leaflet (Y1)
- www.mpm4cps.eu (beginning of Action, updated regularly)
- Thematic Training/Summer Schools on MPM4CPS (yearly)
- Engaging event such as a “CPS Hacker School” (yearly, from Y3)

E.3 Liaison and interaction with other research programmes

This Action focus on MPM for CPS, and these aspects combined are not covered by other COST Actions or EU-projects. As the Action necessarily has to include many aspects of CPS (e.g., mechatronics in several application domains, etc.), there will be links with other research programmes as indicated:

a) Links and complementarity with other COST Actions

- IC0901 - Rich-Model Toolkit - An Infrastructure for Reliable Computer
- IC285 - Modelling and Simulation Tools for Research in Emerging Multiservice Telecommunications

b) Links with other EU research programmes

- ‘Cyber Physical Systems European Roadmap and Strategy’ (CyPhERS). Whereas CyPhERS charts not only technical, but also economic aspects of CPS, MPM4CPS aims to come up with a unified view of modelling for CPS.
- CPS Action Line “Cypher Physical Systems” of the EIT ICT KIC.
- ‘Industrial Framework for Embedded Systems Tools’ (iFEST).
- ‘Combined Model-based Analysis and Testing of Embedded Systems’ (MBAT).

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

The leading role of responsibility in the chairing positions, in the MC and in the WGs will be assigned with a gender balanced approach, as well as with the special concern to involve early stage researchers, whenever possible, on the basis of personal availability.

Identified as potential driving forces for this network, young researchers will be involved in the core of the COST action since its beginning. The Action will provide and encourage young scientists' participation also by arranging for Short Term Scientific Missions (STSM), particularly for early-stage researchers. Their contributions will be presented at the annual Symposia/Conference. It will also be promoted a dedicated track in the Symposia “doctoral Symposium” to involve all the doctoral students involved with the network.

The Training Schools, organized by the Action, as well as the engagement in the management of Working Groups is intended to stimulate the interest of young scientists during the most crucial stages in their scientific career.

The MC will reflect efforts to ensure gender balance during the organization of the symposia in invitations, also for key notes, for WG management and for lead authorship of reports and publications. Early stage researchers will be asked to take care of after-Symposia tasks (preparation of reviews, data collection, etc.), preferentially within the scope of STSMs combined with research visits at guest institutes.

F. TIMETABLE

The Action is planned to run for 4 years.

In the first semester the mission of the Action MC is to particularize, complete and finally agree on the implementation of tasks described in the Memorandum of Understanding.

In the first year, a kick-off workshop will be organized and the basis for the projected scientific work will be established.

On average, one joint MC and WG meeting per year will be held to maintain the momentum of the Action and to closely follow after the Members' activities. Each year, the results achieved within the

Action will be released in a jointly published document available at the Symposium.

In order to state the leading role of CPS Europe, an annual workshop/symposium will provide a suitable platform to disseminate the results to a wider scientific, industry and institutional community. Well known scientists, industry and stakeholders from CPS communities around the world will be invited to take part.

We can summarize the Action in the following manner:

1st year

Schools: Euro-MPM4CPS School (as detailed in H.3.)

Meetings: Working meetings (MC+WG 1 (Kickoff) + 1)

STSM: 3

Annual Workshop MPM4CPS

Industry: Talks at industry events (as detailed in H.2.)

Deliverables:

- Report of activities (define and measure success of cross-WG activities)
- Report on the State-of-the-art of current formalisms used in CPS development: a structured catalogue of tools and modelling languages (updated yearly)
- Draft proposal for a Framework to relate/combine modelling languages and techniques
- Report on current standards and best practices used in CPS, suggest where new standards might be beneficial (updated yearly)
- Benchmark Case Studies proposal (preliminary)
- Report describing the profile of a CPS expert
- A list of existing MPM4CPS courses, with description of education needs

2nd year

Schools: Euro-MPM4CPS School

Meetings: Working meetings (MC/WG 2)

STSM: 3

Annual Workshop MPM4CPS

Industry: Talks at industry events (as detailed in H.2.)

Deliverables:

- Report of activities (define and measure success of cross-WG activities)

- Report on the State-of-the-art of current formalisms used in CPS development: a glossary of terms (domain ontology) to be used in CPS
- Proposal for a Framework to relate/combine modelling languages and techniques
- Report on current standards and best practices used in CPS, suggest where new standards might be beneficial (updated yearly)
- Report on the current industrial state of CPS
- Reports on requirements of each application domain
- List of existing MPM4CPS courses, description of needs (updated version)
- Plan for European Master/Phd Program in MPM4CPS
- Annotated bibliography, annotated who's who, WG reports, (non-)technical publications (updated)

3rd year

Schools: Euro-MPM4CPS School

Meetings: Working meetings (MC/WG 2)

STSM: 3

Annual Workshop MPM4CPS

Industry: Talks at industry events (as detailed in H.2.)

Deliverables:

- Report of activities (define and measure success of cross-WG activities)
- Report of Showcases
- Framework to relate/combine modelling languages and techniques
- Current standards and best practices used in CPS, suggest where new standards might be beneficial (updated yearly)
- State-of-the art on MPM tools and techniques used in different disciplines for CPS development including an efficiency evaluation of MPM tools and techniques on CPS
- Benchmark Case Studies
- Suitability of the different application domain models from a CPS perspective
- List of existing MPM4CPS courses, description of needs (updates)

- Plan for European Master/Phd Program in MPM4CPS.
- Annotated bibliography, annotated who's who, WG reports, (non-)technical publications (updated)

4th year

Schools: Euro-MPM4CPS School

Meetings: Working meeting (MC/WG 2)

STSM: 3

Annual Workshop MPM4CPS

Industry: Talks at industry events (as detailed in H.2.)

Deliverable:

- Report of activities (define and measure success of cross-WG activities)
- Report of Showcases
- Framework (MPM) to relate/combine modelling languages and techniques
- Current standards and best practices used in CPS, suggest where new standards might be beneficial (final, plan for post-Action deployment)
- Suggestions for future MPM4CPS modelling tools and techniques
- Recommendations on the proper use of different models and methodologies in industry case studies
- List of existing MPM4CPS courses, description of needs (updates)
- Start implementation of European Master/Phd Program in MPM4CPS

The Action will support other non-planned events (such as thematic Workshops, Schools, at reputed conferences) as the need and opportunity arises. Best practice guidance and user training documents as well as annual technical reports will be developed jointly within the Action and for release.

The Panel of External Experts will participate in the Symposia and key MC/WG meetings.

Year 4 of the Action will be dedicated to the compilation of a final document summarizing the achieved goals.

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: AT, BE, CH, DE, ES, FI, FR, HU, IT, LV, NL, NO, PL, PT, RS, SE, SI, TR, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 76 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

- International Research community in:
 - * Multi-Paradigm Modeling, its methods, techniques and tools (e.g., language engineering, multi-formalism integration, model transformation tools, consistency)
 - * CPS, its methods, techniques and tools (e.g., concurrent engineering, co-simulation)
- CPS/MPM4CPS Practitioners and Professionals, and their applications (starting from embedded systems, mechatronics, hybrid systems, etc.)
- Industrial players at a national level
- CPS application domains (e.g., Automotive, Aeronautics, Transports, Health applications, Smartcities, Home Automation);
- tool builders (such as LMS, 20Sim, Dassault, Modelon, IDA, Vector)
- EU projects and related initiatives in the areas of MPM and CPS and w.r.t. research, tools and applications
- National (governmental) policy makers: national science foundations, national professional/industrial organizations (e.g., Agoria@Flanders)
- Standards and certification authorities (e.g., Modelica standardisation, OMG, IEEE, ACM)

H.2 What?

The dissemination of the results achieved by this Action will be based on the following methods.

- (1) Annotated bibliography (including a Glossary);
- (2) Annotated list of Research Centers, Laboratories, and Researchers;
- (3) Working Group reports (including state of the art reports, interim reports, case study reports, guidelines, manuals, final reports);

- (4) Articles and non-technical publications for general technical audience (engineers and industry);
- (5) Scientific Publications (classification, surveys) for research audience;
- (6) Publications (tutorials) for an education audience;

H.3 How?

- Web portal www.mpm4cps.eu, thematic mailing list and discussion forums: for all the methods described in H.2.;
- Participation to forums and booths at major events (workshops and conferences such as CPSweek, etc., organised by the MC): for methods (4) and (5);
- Yearly workshop (one per year), co-located with the CPS week, when in Europe, with published proceedings: for methods (4) and (5);
- Yearly talk at relevant reputed industry events (e.g., Design Automation and Testing: <http://www.date-conference.com>, Society of Automotive Engineers: <http://www.sae.org/events/automotive/>): for methods (4) and (5);
- Technical magazines with broad dissemination (e.g., IEEE-Computer): for method (4);
- Peer-reviewed scientific and technical Journals (e.g., SoSym, ASE, ...): for method (5);
- Summer school and Hackerschool: for method (6);

In particular, for the research audience, the Action will provide conferences, workshops and electronic forums, as well as reports and peer-reviewed articles authored by members of the Action and published on major scientific venues. For the educational audience, we will provide online tutorials and books, and organize competitions, and summer schools. Finally, the Action will organize Industrial-driven Tech-Summits on MPM4CPS in order to involve the Industrial audiences.

Research audience:

- a) New conference: MPM4CPS Europe (last year of the Action)
- b) Participation in existing Workshops: MPM, Modelica, ModProd
- c) Participation in existing conferences: CPSweek (when in Europe)
- d) Publications: at major conferences and Journals (SoSym)

Education audience:

- a) Undergraduate/Graduate level: Tutorials, DSLs4CPS competition, HackerSchool (free, non-commercial, open source modeling tools to build CPS);

- b) Doctoral level: Euro-MPM4CPS Summer School (building on and extending the established DSM-TP Summer School organized by the MPM4CPS initiators);
- c) Action Think Tank of Early Stage Researchers which will report to the MC and 4 WGs;
- d) Co-supervision of doctoral (PhD) students.

Industry audience:

- a) Invite major European Industrial application domains around CPS: Avionics, Automotive, Drone Technology, Transportation, Energy, Health, Smart Cities, etc.
- b) Stimulate and guide project proposals, seeded by the Action partners, in the EU Framework Programme.