Towards a European Roadmap on Research and Innovation in Engineering and Management of Cyber-physical Systems of Systems

**What will CPSoS deliver?**

CPSoS will provide a research agenda for Cyber-physical Systems of Systems that:
- Identifies synergies and open issues based on industrial and societal needs, and the state of the art of tools, theories, and methods.
- Proposes promising trans-disciplinary research directions.
- Is driven by the needs of real-world applications.
- Takes a broad, trans-disciplinary view on theories, tools, and methods from several domains.
- Is developed with the help of key researchers and application domain experts.

**What are Cyber-physical Systems of Systems?**

Large, complex, often spatially distributed Cyber-physical Systems that exhibit the features of Systems of Systems

**Cyber-physical Systems (CPS)**
- Tight interaction of many distributed, real-time computing systems and physical systems
  - Examples: Airplanes, Cars, Ships, Buildings with advanced HVAC controls, Manufacturing plants, Power plants, ...

**Systems of Systems (SoS)**
- Many interacting components
  - Large industrial sites with many production units
  - Large networks of systems (electric grid, traffic systems, water distribution)
- Dynamic reconfiguration
  - Components may... be switched on and off (as in living cells) enter or leave (as in air traffic control)
- Continuous evolution
  - Continuous addition, removal, and modification of hardware and software over the complete life-cycle (often many years)

**Partial autonomy**
- Local actors with local authority and priorities
  - Examples: Autonomous systems cannot be fully controlled on the SoS level need incentives towards global SoS goals
  - Examples: Local energy generation companies Process units of a large chemical site

**Emerging behavior**
- The overall SoS shows behaviours that do not result from simple interactions of subsystems
  - Examples: Power oscillations in the European power grid Oscillations in supply chains

**Cyber-physical Systems of Systems**
- Many more examples, e.g. smart energy, water, gas, ..., networks, supply chains, or manufacturing
- High-performance computing and distributed computing technologies
- Dependable computing and communications
- Management and analysis of huge amounts of data (big data)
- Security of distributed/cloud computing and of communication systems
- Next-generation smart sensors
- Advances in human-machine interfaces (HMIs)
- Communication technologies and communication engineering

**CPSoS Consortium**
- TU Dortmund, Germany
- Haydn Consulting Ltd, UK
- TU Eindhoven, Netherlands
- Inno TSD, France
- Local4Global SoS that Act Locally for Optimising Globally, www.local4global.eu

**About the CPSoS Project**
- Supported by the European Commission under the FP7-ICT programme (contract no. 611115)
- Start date: October 1, 2013
- Duration: 30 months
- Budget: 640 000 € (with an EC contribution of 360 000 €)
- Coordinator: Prof. Sebastian Engel, TU Dortmund, Germany
- More information: www.cpsos.eu
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**CPSoS Working Groups**
- Modelling and large-scale simulation
  - Key to design, operation, and improvement of CPSoS
  - Models of CPSoS are large-scale and heterogeneous, and can consist of many components in different languages, software tools, and on different time scales
  - Needed: Large-scale, efficient simulation of heterogeneous Cyber-physical Systems of Systems, including human interactions
  - Dynamic on-the-fly reconfiguration of simulation models
  - Coupling of simulation tools of different strengths without remodelling
  - Management of and consistency guarantees for many different models of different types, time scales, and levels of abstraction
- Traditional management and coordination methods are not suitable due to the partial autonomy of the subsystems (which are often managed by humans)
  - Performance is not only driven by technical, but also by economic, social, and ecological criteria
  - Needed: New methods and tools for such socio-economic systems that take CPSoS properties (autonomy, dynamic reconfiguration, ...) into account
  - Fault-detection, testing, and error handling
  - Faults and unwanted emerging behavior are the norm in CPSoS
  - Extensive system analysis and fault-resilient design are key issues
  - Needed: New methods for the analysis, testing, and verification of CPSoS
  - New methods for the integrated design of resilient CPSoS across all automation and system layers
- New engineering frameworks that support the adaptation, evolution, and maintenance of CPSoS not only during design, but over their complete life-cycle
  - Needed: Methods for the detection of and protection against unauthorized access and data manipulation in internet-connected CPSoS
  - Needed: Integration and management of data collected and stored in heterogeneous systems with different syntax and semantics

**Research & Innovation Challenges**
- Needed: Security and trust
  - Unauthorized access and data manipulation in internet-connected CPSoS
  - Raising public awareness of the impact of CPSoS
  - Identifying key research and innovation directions
  - Stimulating the take-up of research by industry
- Identifying synergies and open issues