



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

Key Research and Innovation Challenges and Medium-term Priorities in Cyber-physical Systems of Systems

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Main Goal:

Define a proposal for a European research and innovation agenda on Cyber-physical SoS

- Not campaigning for a single community, but **bridging between communities**
- **Bottom-up and top-down approach**
 - Analyse the needs in application domains
 - Analyse the state of the art in methods and tools
 - Integrate the two views to define the most important gaps and actions needed

Cyber-physical Systems of Systems (1)



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



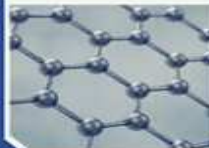
Examples

- › Airplanes
- › Cars
- › Ships
- › Buildings with advanced HVAC controls
- › Manufacturing plants
- › Power plants
- › ...



Many interacting components

Examples



- › Large industrial sites with many production units
- › Large networks of systems (electric grid, traffic systems, water distribution)

Physical connections

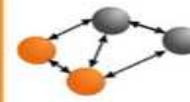


- › Material/energy streams
- › Shared resources (e.g. roads, airspace, rails, steam)
- › Communication networks

Systems of Systems (SoS)

Dynamic reconfiguration

Components may...



- › be switched on and off (as in **living cells**)
- › enter or leave (e.g. in **air traffic control**)

Continuous evolution



Continuous addition, removal, and modification of hardware and software over the **complete life cycle** (often many years)

Examples of Cyber-physical Systems of Systems



Integrated large production complexes

- › Major source of employment and income in Europe
- › Major consumer of energy and raw materials
- › Many interconnected production plants that are operated mostly autonomously with distributed management structures



Transportation networks (road, rail, air, maritime, ...)

- › Vital to the mobility of EU citizens and the movements of goods
- › Large integrated infrastructures with complex interactions, also across national borders
- › Involve multiple organizational and political structures

Many more examples, e.g. smart (energy, water, gas, ...) networks, supply chains, or manufacturing

Partial autonomy

Local actors with local authority and priorities



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



Usually not desired in technical systems, may lead to reduced performance or shut-downs

Examples

- › Power oscillations in the European power grid
- › Oscillations in supply chains

Cyber-physical Systems of Systems (2)



- Key elements of the socio-technical infrastructure
- Providing essential services to the citizens
- Backbone of the industrial infrastructure
- Vulnerable
- Difficult to engineer and to operate
- Good engineering and efficient management of CPSoS is crucial for
 - Energy and resource efficiency
 - Economic competitiveness of the industries
 - Quality of life
- The main potential is on the system level, beyond subsystem control and optimization





- **Distributed management of cyber-physical systems of systems**
 - Decision structures, system architectures, monitoring and fault detection, adaptation, self-organization, integration, trust, humans in the loop
- **Engineering support for the design-operation continuum of cyber-physical systems of systems**
 - Integrated engineering, modeling, simulation, optimization, system-wide and key properties of CPSoS
- **Cognitive CPSoS**
 - Situational awareness, (real-time) big data, reconfiguration and adaptation, analysis of user behavior





- **System integration** and dynamic reconfiguration
- **Resiliency** in large cyber-physical systems
- **Distributed** robust system-wide **optimization**
- **Data-based** system **operation**
- **Predictive maintenance** for asset management
- **Overcoming the modeling bottleneck**
- **Humans in the loop**





- **Industrial production systems:**

Integration of control, scheduling, planning, and demand-side response

- **Manufacturing:**

ICT infrastructures for adaptable, resilient, and reconfigurable manufacturing processes

- **Transportation and logistics:**

Multi-objective optimization of operations in complex, dynamic, 24/7 systems

Safe, secure and trusted autonomous operations





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**Thank you very much for your
attention!**

**Brochure where the state of the art and all
challenges and priorities are described in
detail available for download soon:**

www.cpsos.eu/roadmap



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