
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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# Project Overview

- 33 month Support Action (Oct. 2013 – June 2016)

**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

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# 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)

#### 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

### 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

# 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

# Key Research and Innovation Challenges

- **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

# Medium-term R&I Priorities - Transversal


- **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**

# Medium-term R&I Priorities – Sector-specific

- **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

# 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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