Research & Innovation Challenges

Distributed, reliable, and efficient management of cyber-physical systems of systems

- Decision structures and system architectures
- Self-organization, adaptation, and emerging behavior
- Real-time monitoring, humans in the loop, and trust

Engineering support for the design-operation continuum of cyber-physical systems of systems

- Integrated engineering of the complete life cycle
- Modeling, simulation, and optimization
- Establishing system-wide key properties

Cognitive cyber-physical systems of systems

- Situational awareness in large distributed systems
- Real-time big data analysis for monitoring
- Analysis of operational patterns and user behavior

CPSoS Working Groups

The three CPSoS Working Groups consist of 35 renowned experts in complex systems engineering and applications from industry and academia.

Working Group 1
Systems of Systems in Transportation and Logistics
Chair: Prof. Haydn Thompson, Haydn Consulting Ltd.

Working Group 2
Physically connected Systems of Systems
Chair: Prof. Sebastian Engell, TU Dortmund

Working Group 3
Tools for Systems Engineering and Management
Chair: Prof. Wan Fokkink, TU Eindhoven

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 560 000 €*)
- **Coordinator:** Prof. Sebastian Engell, *TU Dortmund, Germany*

CPSoS Consortium

- TU Dortmund, *Germany*
- Haydn Consulting Ltd., *UK*
- TU Eindhoven, *Netherlands*
- inno TSD, *France*

CPSoS is part of the

European Systems of Systems Research Cluster

AMADEOS
Architecture for Multi-criticality Agile Dependable Evolutionary Open System-of-Systems, www.amadeos-project.eu

CPSoS
Towards a European Roadmap on Research and Innovation in Engineering and Management of Cyber-physical Systems of Systems, www.cpsos.eu

DYMASOS
Dynamic Management of Physically Coupled Systems of Systems, www.dymasos.eu

Local4Global
SoS that Act Locally for Optimizing Globally, www.local4global-fp7.eu

More information: www.cpsos.eu
Contact: sebastian.engell@bci.tu-dortmund.de

CPSoS

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

Scan this with your phone

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

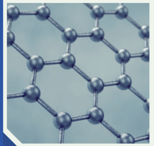
of many distributed, real-time computing systems and physical systems

Examples

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

Systems of Systems (SoS)

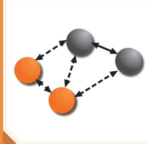
Many interacting components



Examples

- 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)

Physical connections

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

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 movement 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 make use of advances across a number of technological areas:

- 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

Research & Innovation Priorities

Overcoming the modelling bottleneck

- Efficient model building, model validation, and simulation
- Modular multi-formalism multi-resolution models of CPSoS

System integration and dynamic reconfiguration

- Plug-and-play integration and exchange of system elements
- Incremental validation of modifications of the system

Robust distributed control and optimization

- Decision architectures and coordination methods
- Dealing with uncertainty and stochasticity

Resilience in systems of systems

- Strategies for system-wide fault detection and mitigation
- IT security and intrusion detection and prevention

Humans in the loop

- Visualization paradigms that support the acceptance of advanced computer-based solutions and collaborative decision making
- Cognitive models and behavioral analysis of users and operators

Towards cognitive systems

- Monitoring, fault detection, situational awareness and optimization based on large-scale real-time data analytics

Industrial production systems

- Integration of control, scheduling, planning, and demand-side management for plant-wide optimality and a greener economy
- Data-driven asset monitoring and prospective maintenance

Manufacturing systems

- New ICT infrastructures for adaptable, resilient, and reconfigurable manufacturing processes
- Data and information visualization for decision support

Transportation & logistics

- ICT for the support of multi-disciplinary, multi-objective optimization of operations in complex, dynamic, 24/7 systems
- Safe, secure, and trusted operation of partly autonomous systems considering interaction with human users and operators

Roadmap on CPSoS Research and Innovation:

www.cpsos.eu/roadmap