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Cyber-Physical Systems

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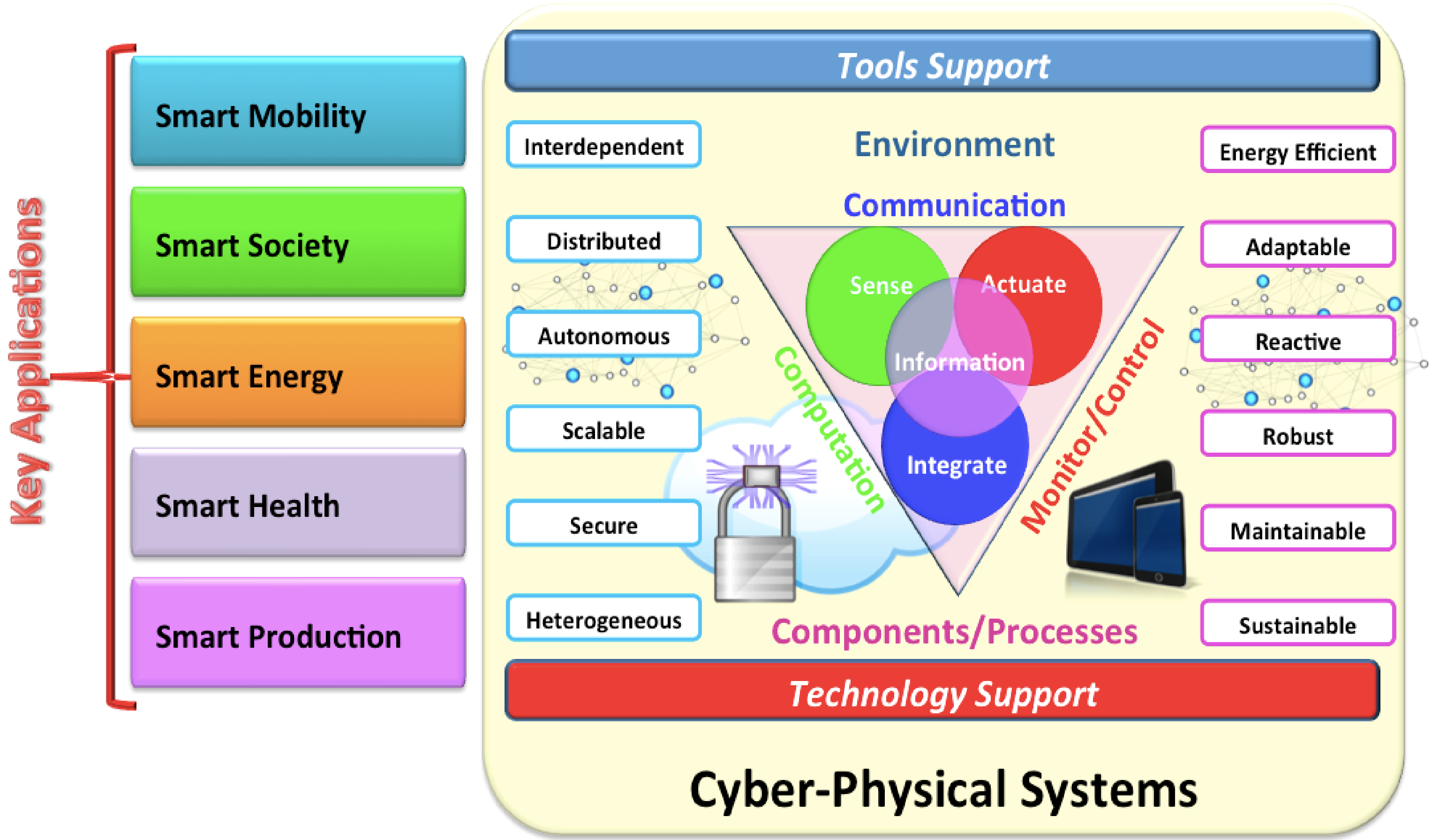
Cross references:	Smart Mobility	Semiconductor Process
	Smart Societies	Equipment and Material
	Smart Energy	System Integration
	Smart Health	Design Technologies
	Smart Production	

CPS(*) as an "enabling technology for multiple key application areas



(*) In our view, CPS includes the "Internet of Things" (IOT) .While Internet of Things mainly deals with communication of sensor, actuators, devices and the cloud CPS, CPS is more general and "..focuses instead on the fundamental intellectual problem of conjoining the engineering traditions of the cyber and the physical worlds"

Objectives

Strengthen the European stakeholder's leadership positions in the new 'digital transformation age' by

- Expand strong research and innovation potential while **overcoming fragmentation** in the European supply base
- Exploit the growing **'Internet Economy' opportunities** .
- Master the complexity, ensuring **safety and security** while **reducing the cost of** utilizing powerful software intensive products/systems
- Enable a more **agile and shorter development cycle**
- Provide support for related **Certification and Standardization** activities as well as for **Education & Training**

Strategy

To reach the stated objectives, the strategy and its implementation are built on:

- **cross-domain** sharing of technologies and research
- The vision of '**virtual vertical integration**' (*) that encourages market leaders to define the conditions for successful business innovation building on emerging technological developments
- A programme approach, with particular emphasis on developing interoperable platforms, using complementary instrumen ts (**focused projects** vs. **"think big"** projects")

The proposed Programmes for the strategy implementation of CPS evolution and market uptake, are structured along the following strategic axes:

- Principles, architectures and models for **dependable CPS**
- Enabling technologies for **autonomous, adaptive and cooperative CP**S
- **Computing Platforms** including hardware, software and communication
- **Digital Platforms** as usable references solutions combining the previous 3 topics

(*) such as GAFA: Google, Apple, Facebook, Amazon.
More could be found at : http://www.supplymanagement.com/news/2013/virtual-vertical-integration-is-the-future-of-supply-chain

Principles, architectures and models for dependable CPS

In order to reduce the effort for establishing the desired interoperability of diverse products and be able to take full advantage of the economies of scale, **developing cross-domain generic principles** for embedded systems engineering and smart systems integration are a technological and economic necessity. The key challenges are:

- **Model driven engineering,** enriching existing methods by multi-domain, multi-dimensional and multi-objective specification and modeling
- **Systems of systems (SoS),** enabling future CPS will be required to work in concert to provide their functionality
- **Reference Architectures** for safe and secure CPSs
- **Multi-/Many-core** systems for real-time and safety-critical applications
- **Dependability 'by design',** and enabling certification (against e.g. ISO26262 in automotive, DO-178/C in aeronautics and Common Criteria) of mixed critical systems in highly complex and non-deterministic environments at affordable costs
- Research on **fundamental challenges** in CPS design

Enabling technologies for autonomous, adaptive and cooperative CPS

- **Safe and robust perception of environment,** dealing with the complexity and the dynamic changes and variability of the real world and with arbitrary complex situations and scenarios in real-time
- **Continuously evolving, systems, learning and adaptive behavior** possibly inspired from biological systems
- **Reliable and trustable decision making, mission and action planning** for safety-related autonomous CPS/SoS that provide stability, safety, security in dynamically evolving system-of-systems
- Issues related to **Human-machine interaction** with autonomous systems
- **Data Analytics for decision support** to realize further system optimization, including data analytics in the loop
- Appropriate **advanced methods and techniques for validation & verification, qualification and certification** of autonomous, adaptive, cooperative systems

Computing Platforms including hardware, software and communication

Cyber-Physical systems encompass a large range of **computing devices and networks.** They must be able to integrate new innovations in order to cope with the user's needs and real world requirements, such as hard real-time constraints, dependability, energy management, efficient data access and storage, dynamic reconfiguration, fault tolerance, easy application deployment and maintenance. The key challenges are:

- Coping with the **complexity of heterogeneous, distributed computing elements**., in particular ensuring the correctness and efficiency of complex heterogeneous distributed systems will be a major challenge, especially concerning the CPS requirements related to **real-time, security, resilience and scalability**
- **Energy efficiency** covering all layers, from silicon, HW, OS, middleware to the system level
- Techniques for **continuously monitoring the performance** of the CPS in order to assess the dependability of the whole system
- Development of specific **accelerators for CPS functions**, like real-time data analytics (streaming analytics), cognitive functions (deep neural networks), cryptology or data security functions,

Digital Platforms

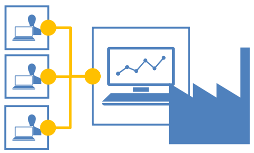
Digital Platforms are usable references solutions combining the previous 3 topics. They allow for the establishment of ecosystems and new business models by using external resources also outside of the CPS (e.g. Cloud based). Research in Digital Platforms will address the following research challenges.

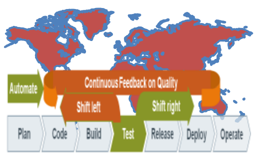
- **Building services in smart spaces based on the capabilities of CPS** and promoting the interoperability of CPS as objects or nodes in Internet
- **Common infrastructure in addition to M2M solution islands** as well as a [global] systems for giving Things digital identities. This should addressed in collaboration with similar EU initiatives dealing with the “Internet of Things
- **Separation of concerns between** platform developers and application developers
- **Provision of common services** which are required by for multiple applications
- **Efficient reuse and composability** by platforms which enable the creation of new products by composing them from a library of pre-validated building blocks. Such platforms such be established as a (de-facto) standard.

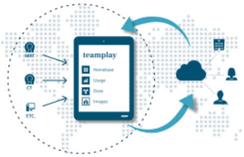
Impact

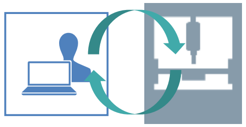
The CPS results will deliver cross-domain solutions with reduced time-to-market and improved trustability. They will **drive the 'digital transformation' of Europe** and eventually lead to a **"virtual verticalisation"** of the European industry to make it competitive to the big vertical non-European companies:

- **Enabling new business models and new services** through digitalisation and by exploiting digital CPS platform capabilities
- **Create greater market opportunities and access greater market share** through new functional and non-functional properties
- **Exploiting the benefits of efficient connectivity and ubiquity of CPS as** the neural system of society in order to address European societal challenges by Smart-X applications (cities, mobility, spaces, health, grid, farming, production)
- **Exploiting CPS technologies for the efficient use of resources** (energy, materials, and manufacturing time)
- **Mastering complexity** while reducing the total cost of ownership and increasing the performance, reliability and security
- **Create Knowledge** through development of new designs, methods and tools in particular for safety-critical high reliability and real-time secure applications
- **Enable continuous evolution and innovation** of existing large scale CPS









CPS Road Map

1	Architectures principles and Models for safe and Secure CPS	Short Term	Medium Term	Longer Term
1.1	Model-Driven Engineering			
1.2	System of Systems			
1.3	Reference Architectures			
1.4	Multi-/manycore systems			
1.5	Dependability by design and enabling certification, resistance/resilience to external cyber-attacks			
1.6	Answering to the fundamental challenges in CPS design			
2	Enabling technologies for autonomous, adaptive and cooperative CPS	Short Term	Medium Term	Longer Term
2.1	Safe and Robust perception of the environment			
2.2	Continuously evolving, systems, learning and adaptive behaviour			
2.3	Optimal control using autonomous CPS			
2.4	Reliable and trustable decision making, mission and action planning			
2.5	Human-machine interaction			
2.6	Data Analytics for decision support			
2.7	Advanced methods and techniques for validation & verification, qualification and certification			
3	Computing Platforms including HW, SW and communication	Short Term	Medium Term	Longer Term
3.1	Coping with the complexity of heterogeneous, distributed computing elements.			
3.2	Energy efficiency			
3.3.	Techniques for continuously monitoring the performance			
3.4	Accelerators for CPS functions			
4	Digital Platforms	Short Term	Medium Term	Longer Term
4.1	Models of Cyber-Physical Systems			
4.2	Building services in smart spaces based on the capabilities of CPS			
4.3	Common infrastructure in addition to M2M solution islands			
4.4	Reference architectures and engineering platforms			
4.5	Separation of concerns			
4.6	Provision of common services			
4.7	Efficient reuse and composability			