Perspectives for System of Systems Engineering in the EU Research & Innovation Programme

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cordis.europa.eu/fp7/ict/embedded-systems-engineering

Outline

- System of Systems: drivers, scope, challenges
- Current EU SoS Projects
- Funding opportunities in FP7 Work Programme 2013
- Practicalities of the call for proposals (budgets, deadline, experts)

Sources for this talk

- EU workshop on Advanced Systems Engineering, Brussels 4-5 July 2012
- IDC study – Design of Future Embedded Systems towards SoS*
- Credit to my colleagues: Alkis Konstantellos, Max Lemke and Philippe Reynaerts
- EU 7th framework programme for research FP7
- Common sense..

*website http://cordis.europa.eu/fp7/ict/embedded-systems-engineering/studies_en.html

System of Systems Example: Bee Hive

European Commission

System of Systems Example: Smart Grid

European Commission

Ad hoc definition: System of systems describes the large scale integration of many independent self-contained systems to satisfy global needs or multi-system request

Drivers

- Increasing number of **interacting systems** with strong connectivity in society and also in industry – "embedded world meeting internet world"

- Growing overall **complexity of systems** has triggered a paradigm shift and the need to enhance the classical view of Complex System Engineering towards SoS Engineering

IDC study – Towards SoS*

Four important Technology Areas

- System Interaction with the Web to exploit ubiquitous access to worldwide information from cars, phones and homes
- New computing paradigms such as multi-core technologies
- New ways of Interaction and Cooperation with complex data through visualisation and smart data analysis
- Critical requirements for the design of future dependable systems to guarantee security and safety

*IDC study - Design of Future Embedded Systems towards SoS, website http://cordis.europa.eu/fp7/ict/embedded-systems-engineering/studies_en.html

Scoping of SoS

Maier's Criteria 1998

Five <u>typical</u> dimensions to a System-of-Systems:

- **Geographic distribution**
- **Operational independence** of the elements
- **Managerial independence** of the elements
- **Evolutionary development**: SoS evolves over time, developing its capabilities as the constituent systems are changed, added or removed.
- **Emergent behaviour**: SoS itself offers additional services above and beyond the capabilities of the constituent systems (may also exhibit unexpected and potentially damaging behaviours)

But need connectivity and sharing of knowledge to drive SoS towards goals

Paradigm shift through SoS

Hermann Kopetz
EU workshop 4-5 July

European Commission

Characteristic	Old-Classic	New-SoS
Scope of System	Fixed (known)	Not known
Specification	Fixed	Changing
Control	Central	Distributed
Evolution	Version controlled	Uncoordinated
Testing	Test phases	Continuous
Technology	Given and fixed	Uncertain
System development	Process model	????

No good model, dynamic evolution, mixed criticality systems - certification!!

System of Systems
EU workshop 4-5 July

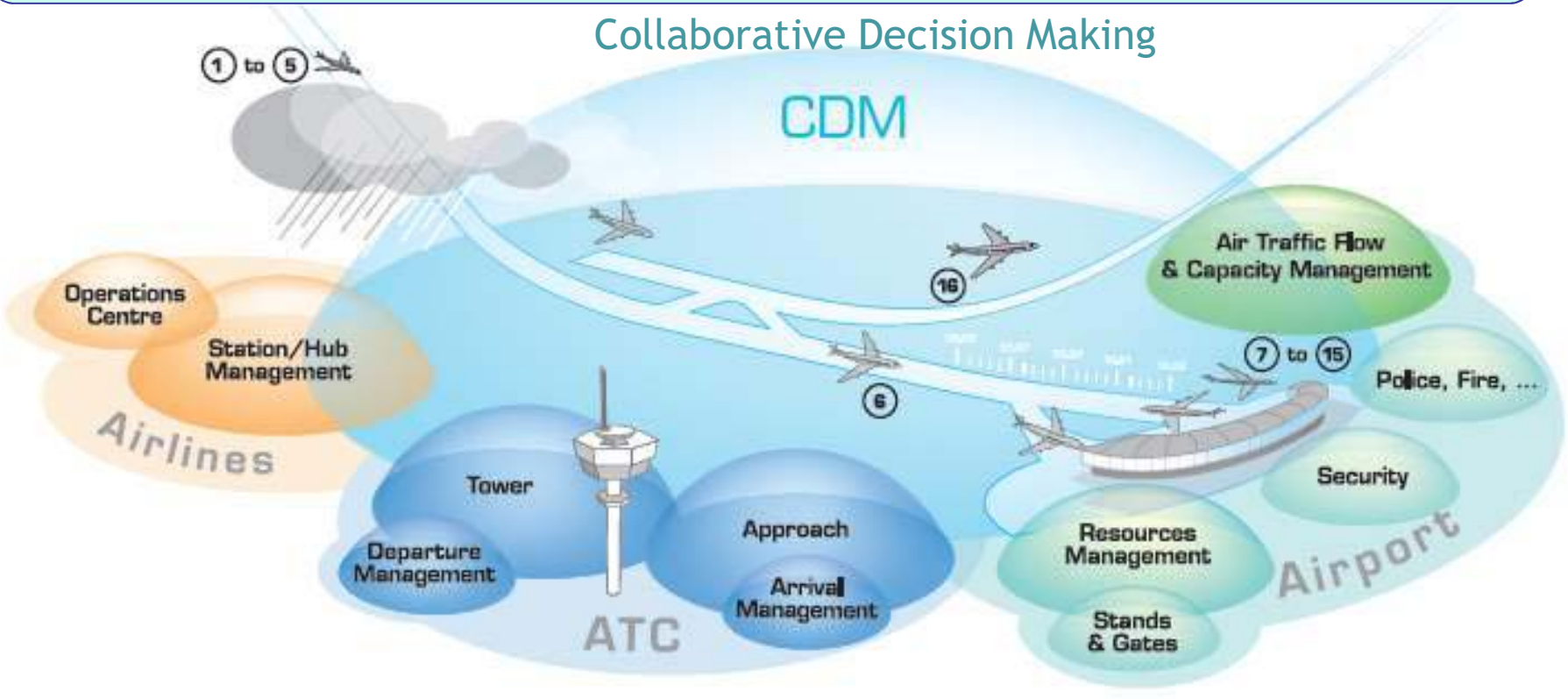
Types of SoS

Type	System	System of Systems	
Man Made	Car, Road	Product range, Integrated Traffic System	*ICT Powered*
	Aeroplane	Airport, Air Traffic Control System	
	Computer	Distributed IT System	
	Building	Town, Shopping Mall	
Biological	Animal, Plant	Herd, Forest	
Sociological	Family, Club, School, Local Church	Town, Nation, the Education System, religion	
Environmental	Weather, a river	The eco-system	
Organisational	Company	Supply Chain, Global Enterprise, the Stock Market	
Political	Town Council	National Government, EU, UN	

Controlling Systems -> Influencing Systems

An example: Air Operations

Make several systems working together and get synergy towards common objectives: end-to-end services, traffic, energy, time, etc.

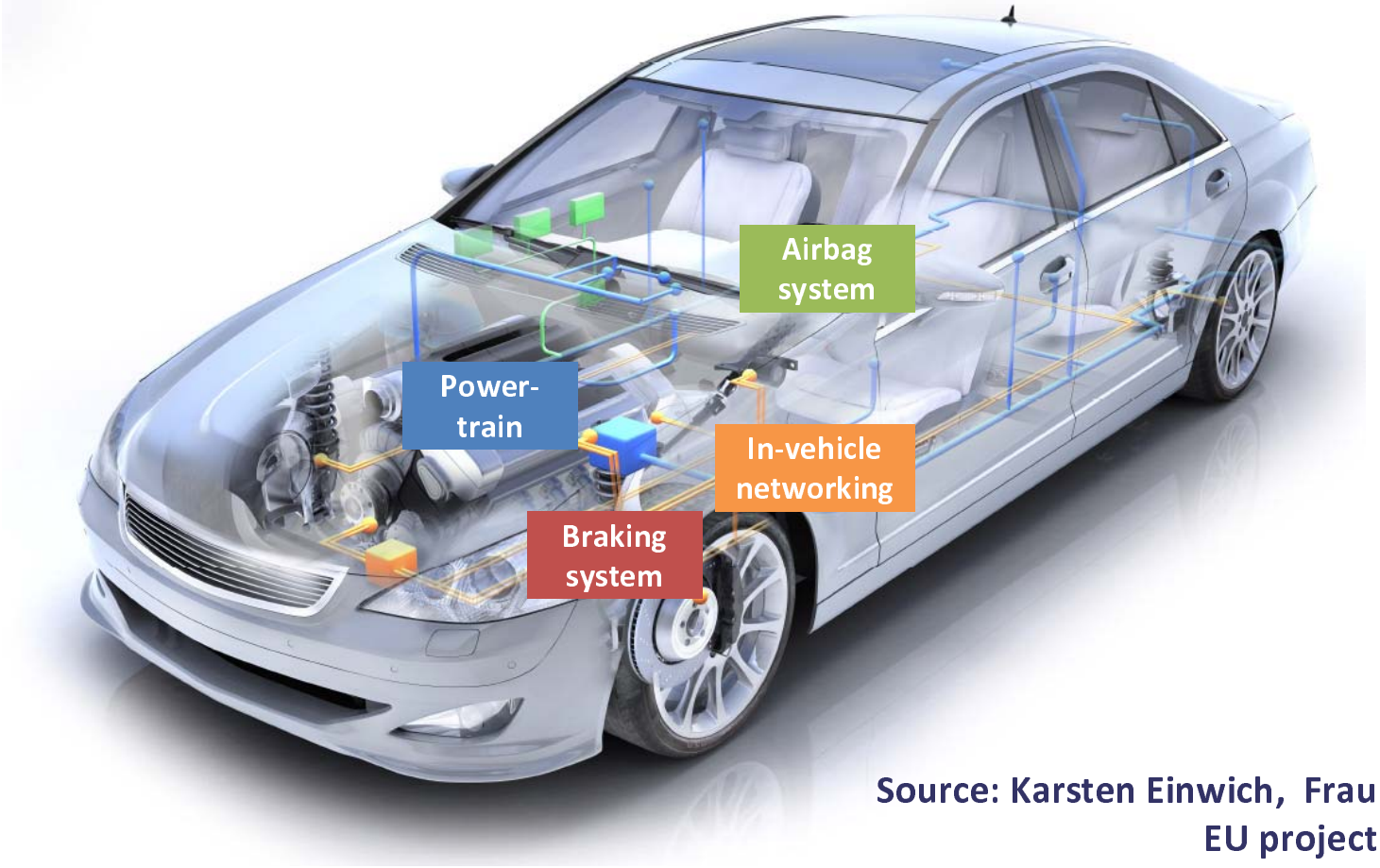


Implementation of SoS has already started [more or less known as such]
Any ICT progress can be transformed rapidly into a benefit.

Source: Jean-Luc Garnier, Thales

Another example

Automotive



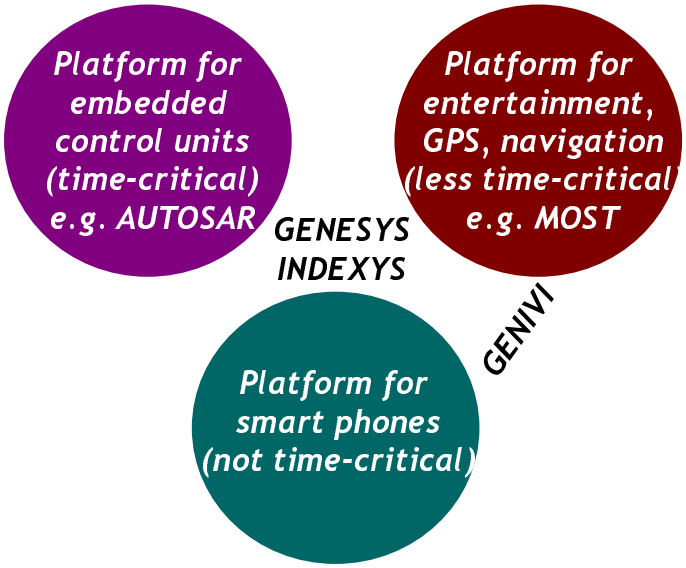
Source: Karsten Einwich, Fraunhofer
EU project VERDI

From Advanced Control to Systems of Systems

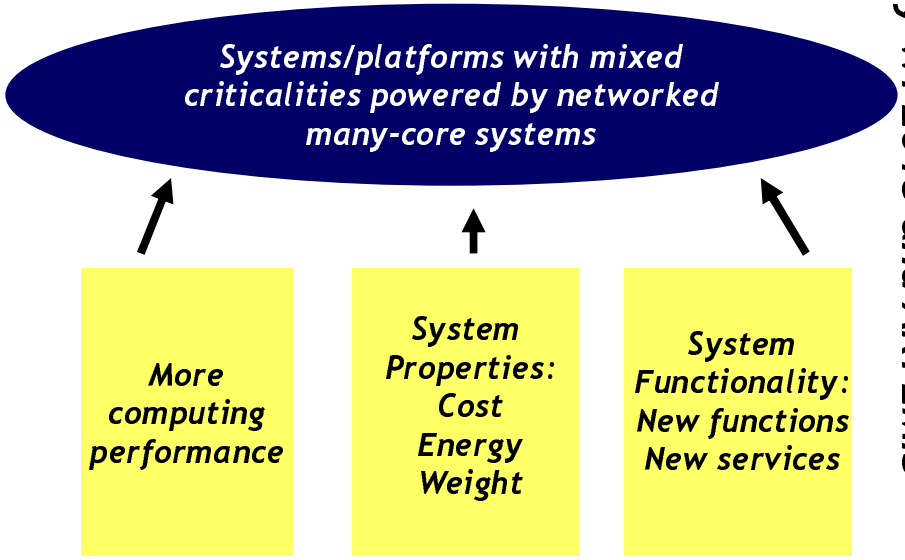
European Commission

Automotive

Today's Reality: Independent Systems



Under Preparation:



Intended to be supported by WP2013 and ARTEMIS

Potential scenario/vision for HORIZON 2020

Future: Autonomous Driving

- **System of systems** with emergent behaviour
- **Mixed criticalities** – priority to safety and time-criticalities
- **Cognitive control** – learning, simulation capabilities
- Data provided by **wireless sensor networks** and the **IoT**
- Powered by a **computing continuum**

System of Systems EU workshop 4-5 July

More Examples

- **Water management** - treatment, reservoir management, flow control, pumping, and sewage treatment
- **Traffic control** - flow control, signalling, automated highways, driver information, navigation
- **Emergency response** – coordination of ambulance, medical treatment, medical information, disaster management
- **Air traffic control** – routing, radar detection, transponder information, satellite tracking, avionics and communications
- **Smart Grid** – more intelligence in distribution network (fossil, wind, PV, storage)
- **Railways** – signalling and operation across borders
- **Satellites**- coordination of satellites for imaging/provision of services, e.g. communications
- **Distributed control systems**
  - **Automotive systems** – increased integration of mixed signal electronics with mechanical components
  - **Automation** – factories and manufacturing
  - **Process Control** – large chemical plants

Geographical Distribution?

Need documented experience of exemplars!

IDC study – Towards SoS

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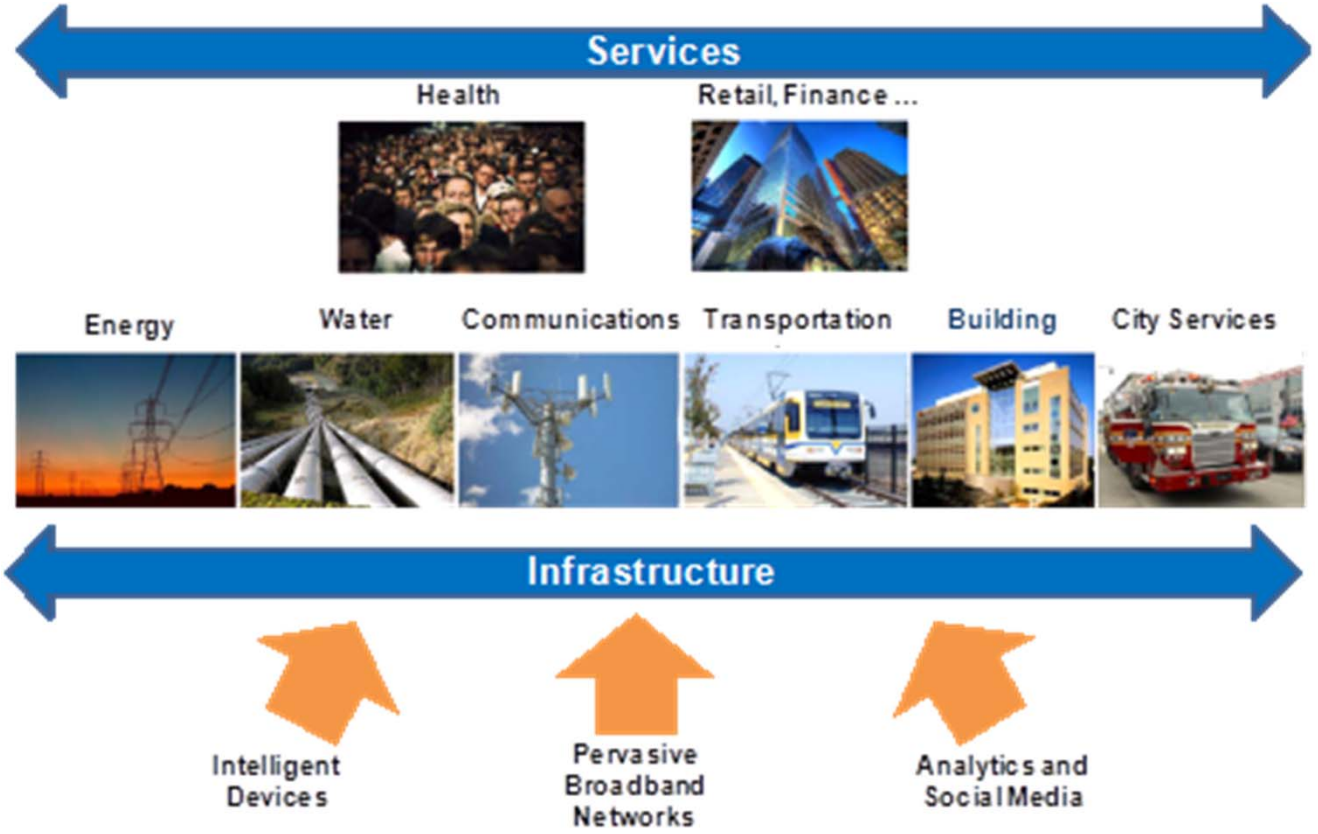
Business view

Infrastructure & last node



Embedded Systems market worldwide revenue, 2010-15

Worldwide Embedded Systems Revenue, 2010–2015 (€Million)

Industry	2010	2012	2015	2010–2015 CAGR (%)
Automotive	58,211	78,848	103,289	12.2%
Industrial(1)	132,343	158,739	207,383	9.4%
Healthcare	43,650	54,266	75,048	11.4%
Energy(2)	41,275	64,564	180,909	34.4%
Communications	330,024	458,623	614,458	13.2%
Consumer	246,554	284,503	333,050	6.2%
Total	852,057	1,099,543	1,514,137	12.2%

Notes:
(1) Includes aerospace and defence, industrial automation, services (kiosks, PoS, video surveillance, test and measurement), industrial PCs, handheld terminals.
(2) Includes energy consumption points (home/building), renewable energy, electricity T&D

Source: IDC, 2011

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Challenges

- Technological
  - Multidisciplinary approach (common language)
  - System Modelling, Simulation (and Verification)
  - Emergent Behaviour
  - Novel methods, architectures, platforms and theory
  - Standards – too early, perhaps requirements?
- Economic
  - Demonstrating business benefits, Quality of Service, availability (consequential loss)
- Societal - User Acceptance and Legal
  - Mixing Criticality – Security and Safety
- Education

Need for Case Studies!

Business benefits

- Business benefits for industry?
- Performance benefit for SoS owners?
- Added value of SoS approach across industrial sectors?
- Any commonalities in methodology?

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Immediate Needs

- Develop methods, architecture platforms and theory for SoS applied to a number of case studies (more than one but not many)
- Develop multi-scale, hierarchical modelling and simulation capability to provide decision support tools for industry to assess the potential benefits of SoS
- Identify commonalities across case studies
- Identify and build the constituency and stakeholders in SoS

Stakeholders

- **Disciplines**: systems engineering, software engineering, mathematics, natural sciences, social sciences, economics..
- **Stakeholders** apart from academia: system integrators, system designers, tool vendors, infrastructure operators, public authorities..

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The EU ICT Programme

Evolution of SoS(E)

2010-2012 Exploratory	2013 Driven by Use Cases	2014-2020 (H2020) ??
1st EU call for R&D proposals in SoS(E)	Work programme 2013 launched	WP 2014 in Preparation
4 projects funded (16 M Euro)	Includes slots for SoS (R&D and support) Funding depends on quality of SoS proposals.	SoS topic is under consideration, or linked to themes such as Complex systems, Smart spaces, or Advanced Systems (design and engineering).
3-4 other projects partly doing SoSE (~ 4M Euro)	(Total 72.5 M Euro for four topics, see foil on objective 3.4)	We need convincing arguments incl. market data

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On-going SoS Research

Support Actions

T-Area SoS:
- Towards a SoS roadmap
- Supply-side driven
- Top-down approach
- System Engineering
- US-EU

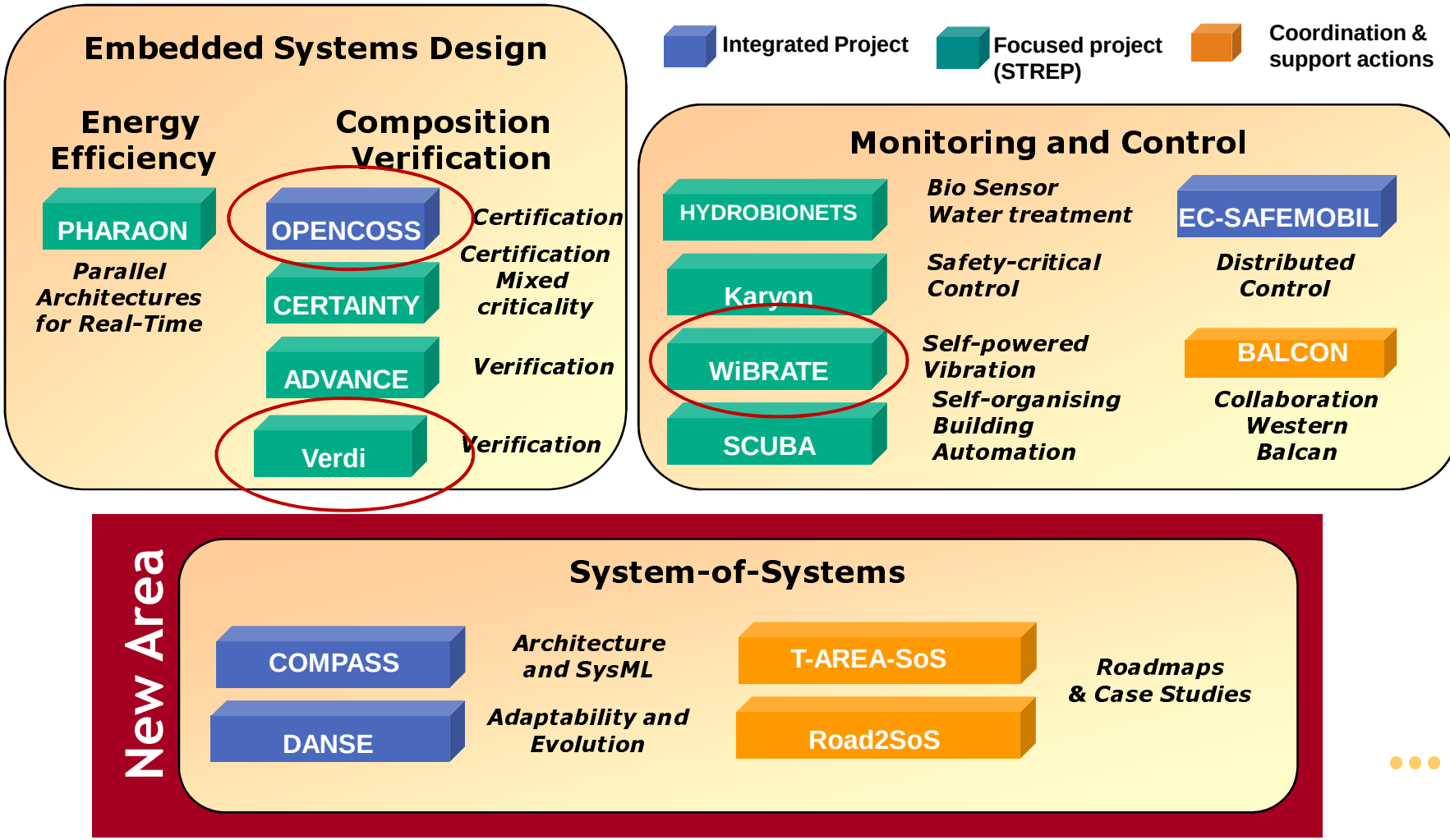
Road2SoS:
- Towards a SoS roadmap
- Sector/demand-side driven
- Bottom-up approach
- Consulting industry experts
- Energy, Manufacturing, Crisis Management, Traffic Control

DANSE:
- Designing for adaptability and evolution in SoS Engineering
- SoS engineering approaches
- Air Traffic Management; Autonomous Ground Transport; Water Treatment & supply

COMPASS
- Comprehensive Modelling for Advanced Systems of Systems
- Model-based tools
- Emergency Response; Audio/Video/Home; Automation Ecosystem; Integrated Modular Avionics

Integrated projects

The EU ICT Programme Portfolio Call 7, 2011



Objective ICT-2013.3.4 Advanced Computing, Embedded and Control Systems

R&D ~69 M€

IPs:

- Next generation of energy and cost efficient servers for Data Centers
- New platforms addressing mixed criticalities: embedded systems meet the Internet

STREPs:

- Exploit synergies and strengths between computing segments
- **From analysing to controlling behaviour of Systems of Systems**

Support actions ~3.5 M€

CSAs:

- Access to novel computing technologies for industry
- **Constituency building, roadmapping**

From analysing to controlling behaviour of SoS

STREPs

- Analysing and modelling SoS
- Validating new SOS engineering approaches in industry-driven case studies, e.g.:
  - Distributed energy systemes and grids
  - Multi-site industrial production
  - Automated transportation
- Stress generic approaches, elaborate basic concepts, identify open research issues

Constituency building & road-mapping

CSAs

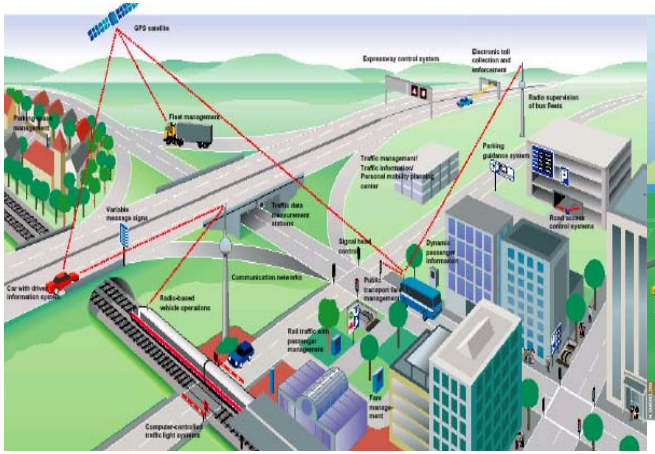
- Co-ordinate SoS related projects towards deriving common concepts and research challenges and building constituencies for a European Research & Innovation agenda on SoS
- …

European Commission

Motivation

Several autonomous systems function as an integrated system to satisfy broader needs

- From design to engineering of SoS
- Embedded world meets the Internet
- Take a holistic view of SoS with emergent behaviour
- Follow a generic approach across different SoS
- Beyond "best effort": satisfy non-functional properties
- Find the balance between co-operation and autonomy



ARTEMIS Joint Undertaking

ARTEMIS Call 2012

- ARTEMIS Sub-programmes on embedded systems research
- ARTEMIS Innovation Pilot Programmes:
  - ✓ AIPP1: Critical Systems Engineering Factories
  - ✓ AIPP2: Innovative Integrated Care Cycles
  - ✓ AIPP3: Smart environments - the Neural System for Society
  - ✓ AIPP4: Production and Energy Systems Automation
  - ✓ AIPP5: Computing platforms for embedded systems
  - ✓ AIPP6: "Intelligent-Built" environment and urban infrastructure for cities
- Closing: Late summer – 1-step submission procedure

Two complementary programmes - FP7 and ARTEMIS JTI:

FP7: targeting new paradigms, foundational research, cutting across applications with mid- to long term horizon.

ARTEMIS: closer to market targets, application focus, reference architectures, pilot demonstrations, migration pathways for legacy

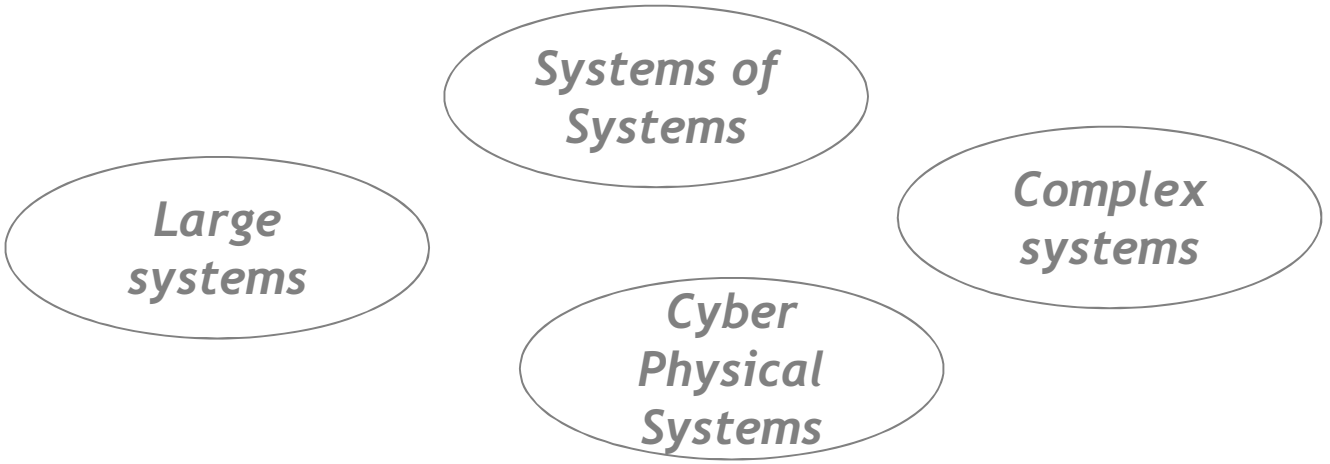
Leadership in Enabling and Industrial Technologies

- Strategic, **technology focused** approach
  - With applications in many sectors/ challenges

- **A new generation of components and systems: engineering of advanced and smart embedded components and systems**
- **Next generation computing: advanced computing systems and technologies**
- **Future Internet: infrastructures, technologies and services**
- **Content technologies & information management: ICT for digital content and creativity**
- **Advanced interfaces and robots: robotics and smart spaces**
- **Micro- and nanoelectronics and photonics**

- Differentiated from:
  - *Societal challenges*: **demand led**, combining different technologies/ solutions
  - *European Research Council*: **Bottom up, Foundational**

Advanced Systems in Horizon 2020: ?



Dependability

Emergent properties

Dealing with uncertainty

Research Opportunities in FP7-ICT WP2013

Proposers' Day

European Commission

Ministry of Science and Higher Education
Republic of Poland

National Contact Point in POLAND

ICT Proposers' Day 2012
26-27 September, Warsaw
Networking for European ICT R&D

- **Aim of the event:**

to prepare for the Calls for proposals of the new ICT WP2013 (1.5 billion € of funding)
  - by networking and partnerships building
  - by first-hand information from EC officials

- **Structure:**

  - thematic sessions with presentations of proposal ideas
  - information stands & bilateral meetings

- **Registration:**

free of charge, open from the end of June 2012

http://ec.europa.eu/ictproposersday

More information

- Call for proposals
  - Deadline for call 10: January 2013
  - Work programme 2013: www.cordis.europa.eu/fp7/ict
  - Background information: www.cordis.europa.eu/fp7/ict/embedded-systems-engineering
  - Proposers' Day, 26-27 Sept.: www.ec.europa.eu/ictproposersday
  - **For specific questions**: werner.steinhoegl@ec.europa.eu
- Call for evaluators: Please register in our database www.cordis.europa.eu/emmfp7

Wanted: Experts in SoS, SoSE and in related enabling technologies such as simulation, modeling, software engineering, dependability & real time, large scale /complex systems, control engineering, optimisation,..

Conclusions

- Research opportunities for SoS(E) in the European ICT work programme 2013. Important:
  - Link research to use cases
  - Involve industry
  - Emphasize ICT content
  - Explain added value of the SoS approach
- Think of SoS success stories and disseminate them
- Contribute to networking and roadmapping activities of the two running support actions T-AREA-SoS and Road2SoS
- Future: Evolution of the area SoS(E) in the EU programme depends on the success of the activity

- Send us some good proposals..