European Systems related R&D

An overview and outlook:"Computing, Embedded, Control and Cyber-Physical Systems"

Workshop "Control for Cyber-Physical Systems"
London UK , October 20-21, 2012

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Disclaimer

- The information in this paper reflects the views of the author and not necessarily those of the European Commission on this subject.

Note: *For detailed information and deadlines about future calls for proposals and H2020 see www.cordis.europa.eu, www.ec.europa.eu and www.cordis.europa.eu/fp7/ict/embedded-systems-engineering*

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1. "Systems R&D" evolution in EU public R&D programmes
2. Embedded Systems, Control and SoS in FP7 (2007-2013)
3. CPS towards H2020
4. Remarks on Control
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EC CONNECT Directorate General

(since July 1st 2012; previously ICT)

- Director General: Robert Madelin
- Directorate A: Components and Systems

  Director: Khalil Rouhana
- Unit A3: Complex systems & Advanced computing

  (since July 1, 2012;previously *Embedded systems and Control*)

  Rainer Zimmermann (Head), Max Lemke (Deputy), Ioannis Bitsios
  Francesca Flamigni, Erastos Filos, Alkis Konstantellos, Markus Korn,
  Zulema Olivan-Thomas, Rolf Riemenschneider, Danuta Seredynska,
  Werner Steinhoegl, Panos Tsarchopoulos,

Evolution of the "embedded and control" systems domain in Europe (EC)

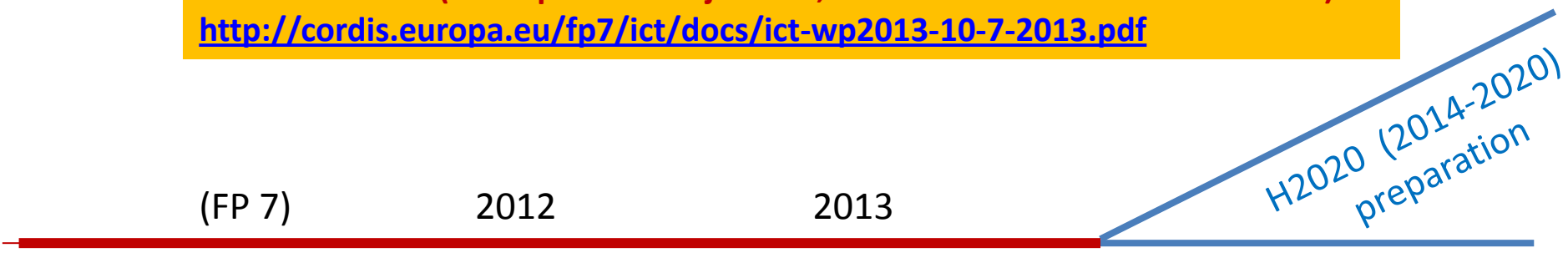
- Open Microprocessor Systems (OMI), (1996) (*)
- Embedded Systems (2000) - New Unit "EMS"
- Networked Embedded Systems (2004)
- Embedded Computing , ARTEMIS, SRA-1, (2006)
- Networked Embedded & Control Systems, incl. WSN (2007)- New unit "EMS & Control"
- Systems of Systems, SoS Engineering (2009)
- Embedded Computing, ARTEMIS JU (SRA-2, 2011)

  -New unit: "Complex Systems & Advanced Computing" (7/2012)
- ***Under consideration:*** *CPS (for Horizon 2020) , see discussion in this presentation ->*

(*)Dates are approximate, OMI= Open Microprocessor Initiative, EMS= Embedded Systems, SRA=Strategic Research Agenda, J U= Joint Undertaking

The last calls for proposals in FP7/ICT

! Check call text (description of Objectives, Evaluation Criteria and Deadlines) in:
http://cordis.europa.eu/fp7/ict/docs/ict-wp2013-10-7-2013.pdf



Some systems related objectives (simplified)! :

- **Computing, data centers**
- **Mixed criticality systems (embedded)**
- **(Control of) Systems of Systems**
- **Synergies between embedded and HP Computing**

- **Future Internet**
- **Robotics and cognitive systems (Jan 15, 2013)**
- **Advanced manufacturing-FoF (Dec 4 ,2012)**
- **EU - Brazil in "embedded and control" (Dec 12, 2012)**

← parts of ICT 2013 Objective 3.4 ,
Budget 72 Mi Euro,
Deadline Jan. 15, 2013 (see Cordis)

ICT call for proposals in Systems of Systems

The ICT Work Programme (WP) 2013 call for proposals includes a topic in SoS under objective 3.4

See detailed call text and associated "impacts“ on the web

Call coordinator:
Dr Werner Steinhoegl
CONNECT A3

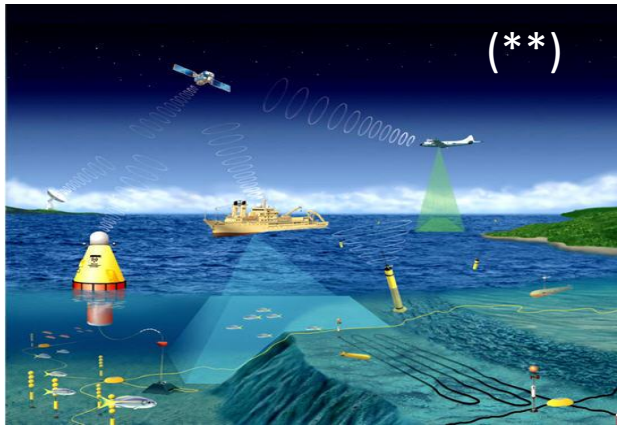
*www.cordis.europa.eu/fp7/**ict**/docs/draft-**wp2013**.doc*

Objective ICT-2013.3.4
Advanced computing, embedded and control systems

Part d):
From analysing to controlling behaviour of Systems of Systems (SoS)

Systems of Systems and SoS(E)ngineering

Some general challenges for civil SoS(E) applications.

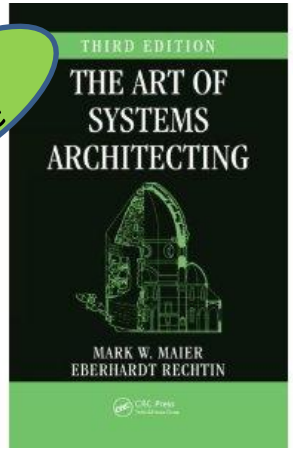


1. **Real time, dependability and control for SoS(E)**
2. **M.Maier criteria and DoDAF/MoDAF (***)**
3. **Modeling and simulation for SoS**
4. **Standards/standardization efforts**
   (e.g. IEEE P2030 /smart grid, March 2012, includes some SoS concepts, <>)

Sources:
(*) SAAB Security Systems, Brussels meeting 2012
(**) IOOS Observatory system, 2011
(***) MITRE Corporation(USA), DoD(US), MoD (UK) Architectural Framework
(<>) IEEE P2030: http://grouper.ieee.org/groups/scc21/2030/2030_index.htm

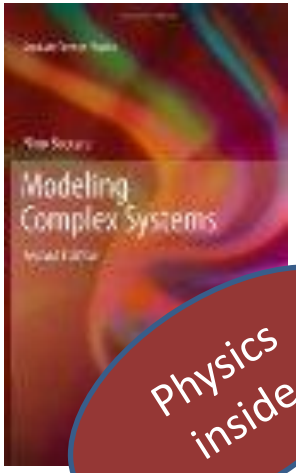
Various aspects of SoS(E)

Mark Maier



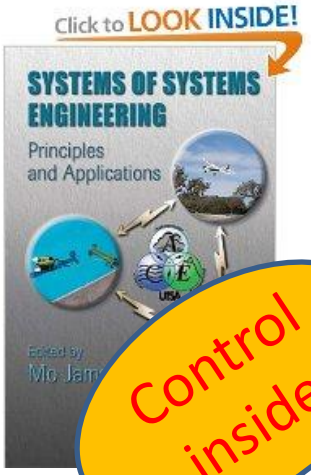
SE inside

Nino Boccara



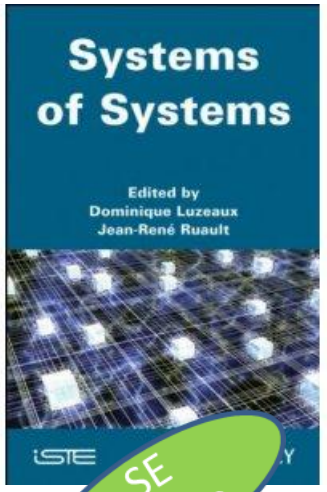
Physics inside

Mo Jamshisi

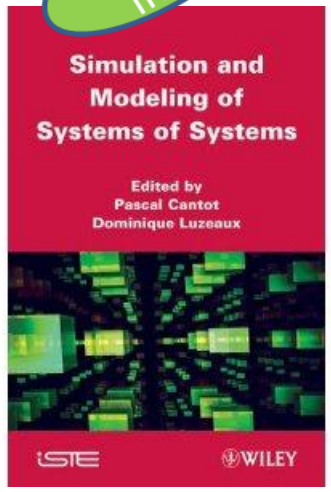


Control inside

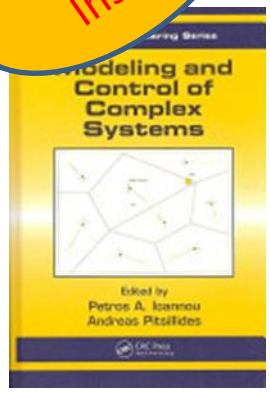
Dominique Luzeaux



SE inside



Control Inside

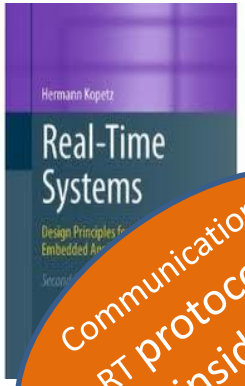


P.Ioannou & A. Pitsillides

Eberhard Rechtin

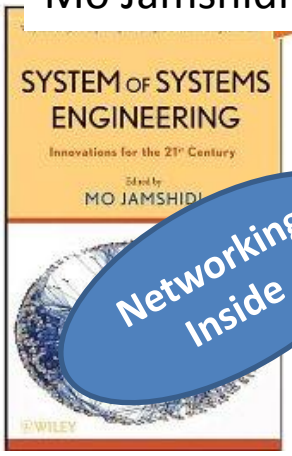
SE inside

Hermann Kopetz 2nd ed. 2012



Communication RT protocols inside

Mo Jamshidi



Networking Inside

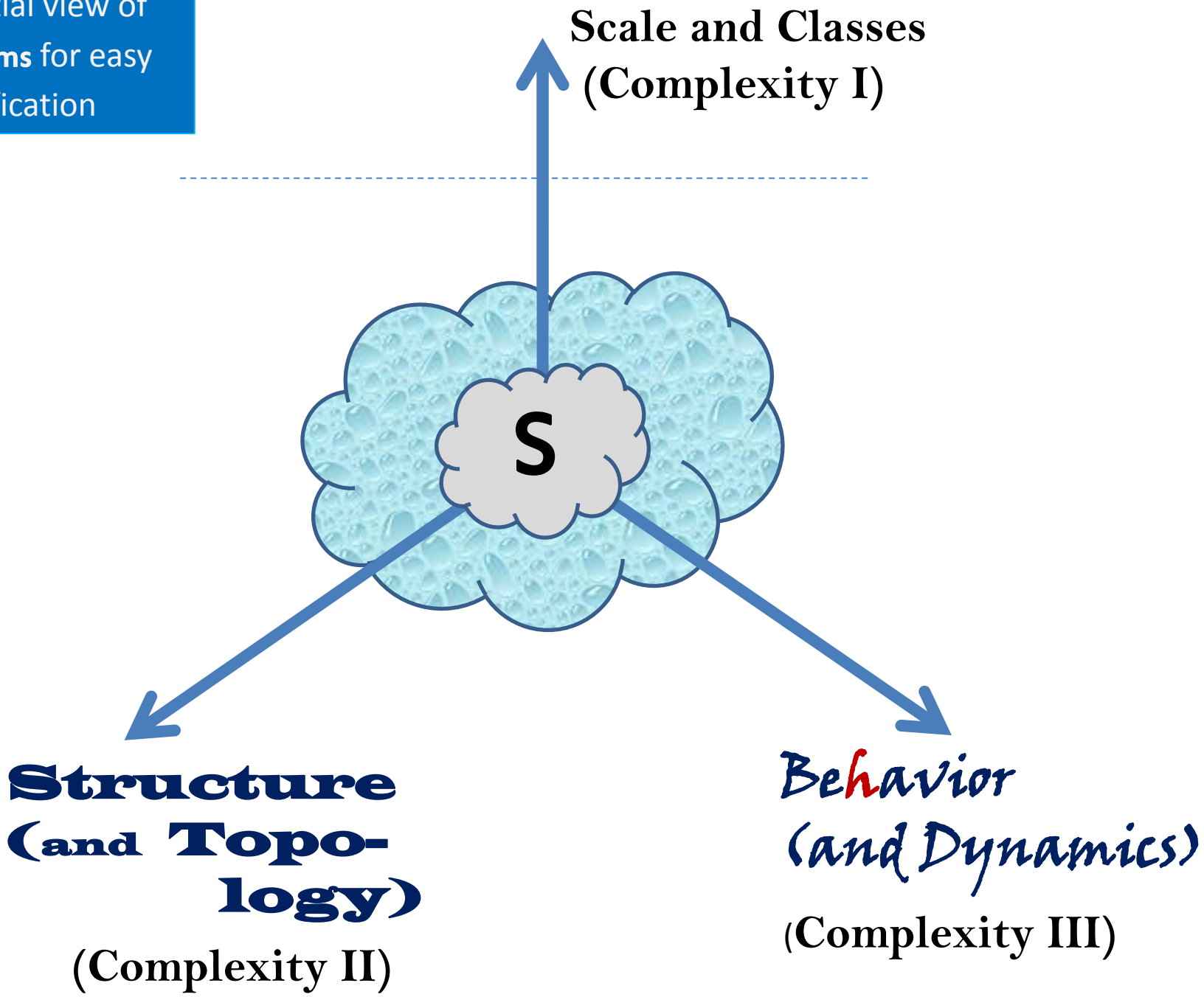
SE= Systems Engineering

European CPS related activities and initiatives (examples)

- German Government CPS initiative & Roadmap (Acatech = Academy of Science and Engineering)
- University level CPS R&D (e.g. Germany, Austria, Denmark)
- ERC (European Research Council): CPS call (2012)
- EIT ICT Labs (EIT =European Institute of Innovation and Technology) established a CPS area (2011)
- ERCIM/ SAFEPROCESS CPS initiatives
- Marie Curie CPS fellowships (2012)
- ARTEMIS CPS related topics & projects (SRA-2)

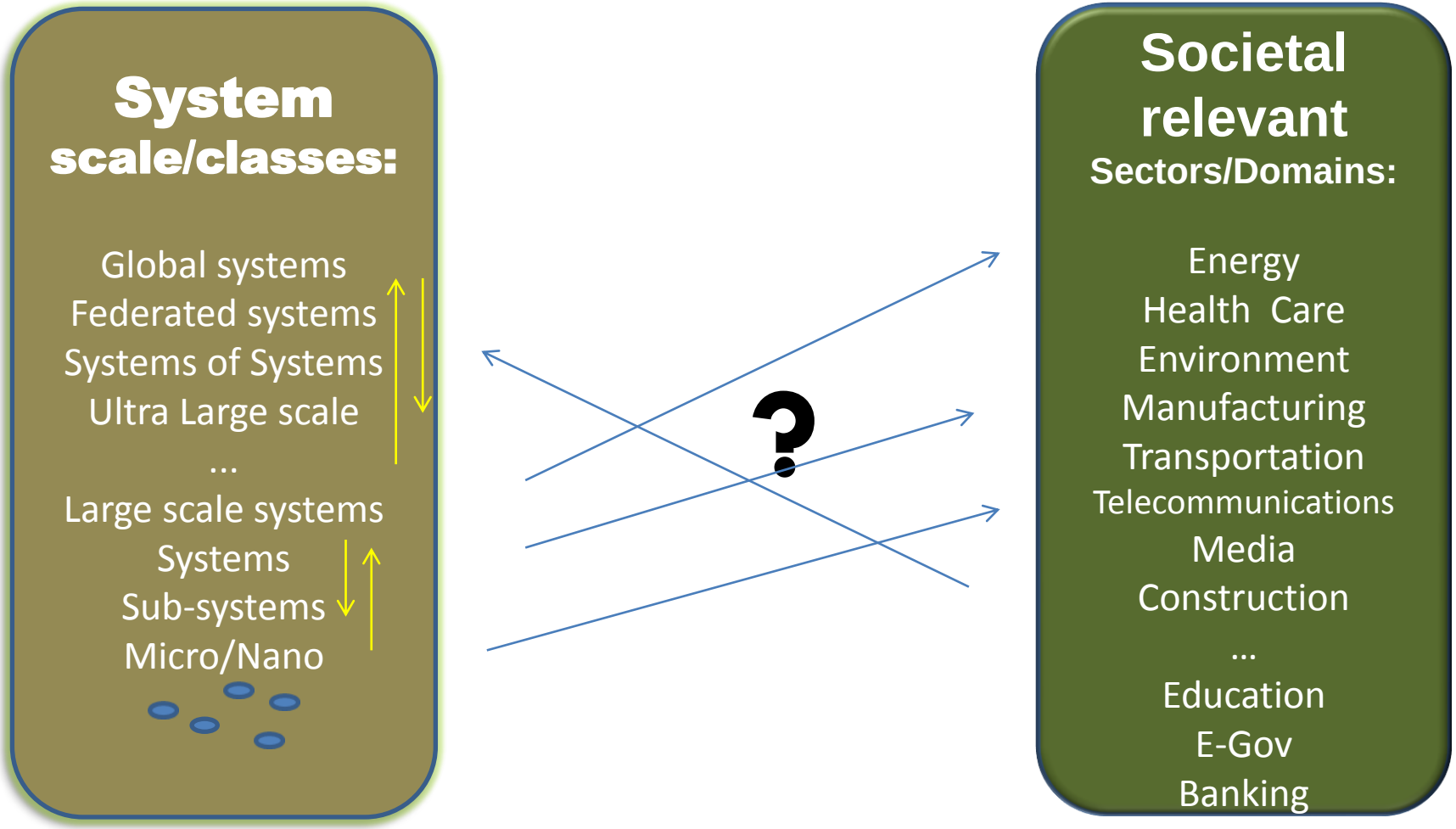
Note: References at the end of this presentation

A partial view of **S**ystems for easy classification



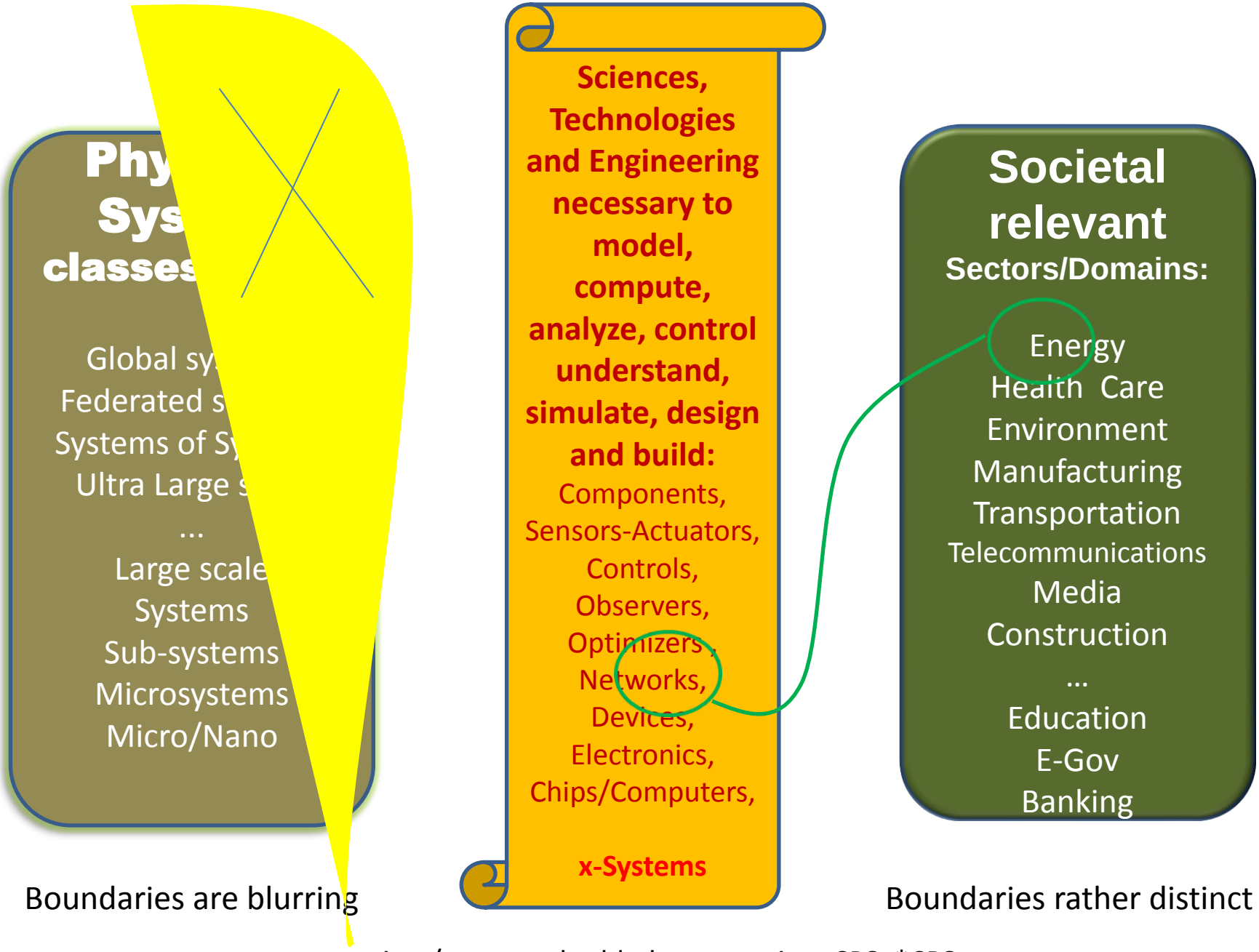
Boundaries are blurring

Boundaries rather distinct

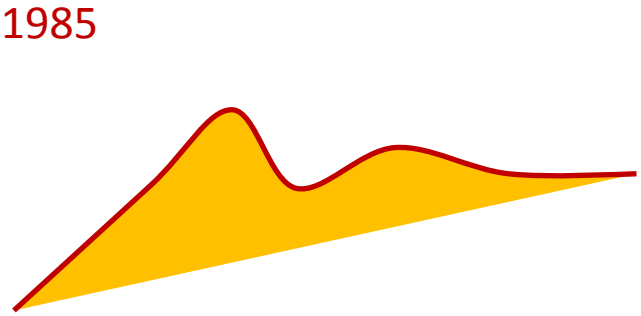


Scientific, or intuitive classification.
Physical and most of them with
ICT-based Engineered systems

The related economies, Capital
Equipment, Systems, Infrastructures
Workforce, Society,


R&D and Industry
Phy
Sys
classes
Global sy
Federated s
Systems of Sy
Ultra Large s
...
Large scale
Systems
Sub-systems
Microsystems
Micro/Nano
Sciences, Technologies and Engineering necessary to model, compute, analyze, control understand, simulate, design and build:
Components,
Sensors-Actuators,
Controls,
Observers,
Optimizers ,
Networks,
Devices,
Electronics,
Chips/Computers,
x-Systems
Societal relevant
Sectors/Domains:
Energy
Health Care
Environment
Manufacturing
Transportation
Telecommunications
Media
Construction
...
Education
E-Gov
Banking
Boundaries are blurring
Boundaries rather distinct
x=micro/nano, embedded, automation, CPS, *CPS ...

Converging to a "**post-embedded systems**" topic



1985

2012

Autonomic Computing (**7**)

Ubiquitous/ Pervasive Computing

Networked ***(2)*** Embedded and Control Systems

Networked Embedded Systems

Embedded (Systems) ***(1)***

Embedded Software

Micro-Controllers, FPGAs, …

Systems of ***(6)*** Systems

Complex Systems

Large Scale Systems

Adaptive Systems

Ultra ***(3)*** Large Scale Systems

CaSoS ***(4)***

*CPS

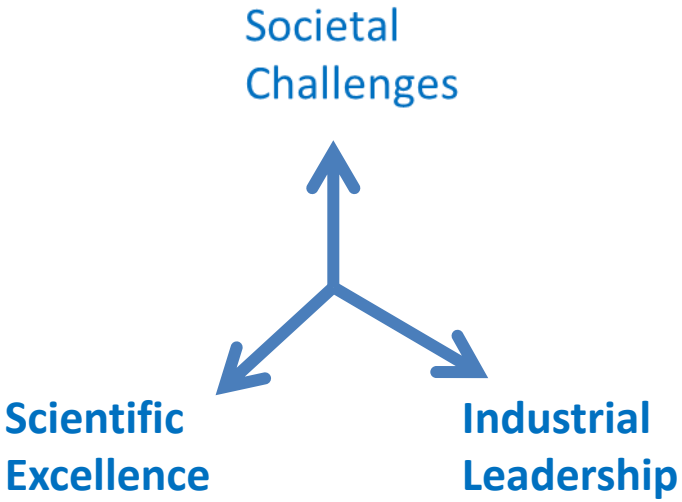
CPS ***(5)***

CPS= Cyber-Physical Systems

Notes: Introduced and promoted mainly by: **(1)** NSF / ICT, **(2)** ICT, **(3)** Carnegie Mellon/SEI, **(4)** Sandia Labs, (5) NSF , (6) DoD(US)/MoD (UK), DGA(FR) and ICT(EU, 2009), (7) IBM

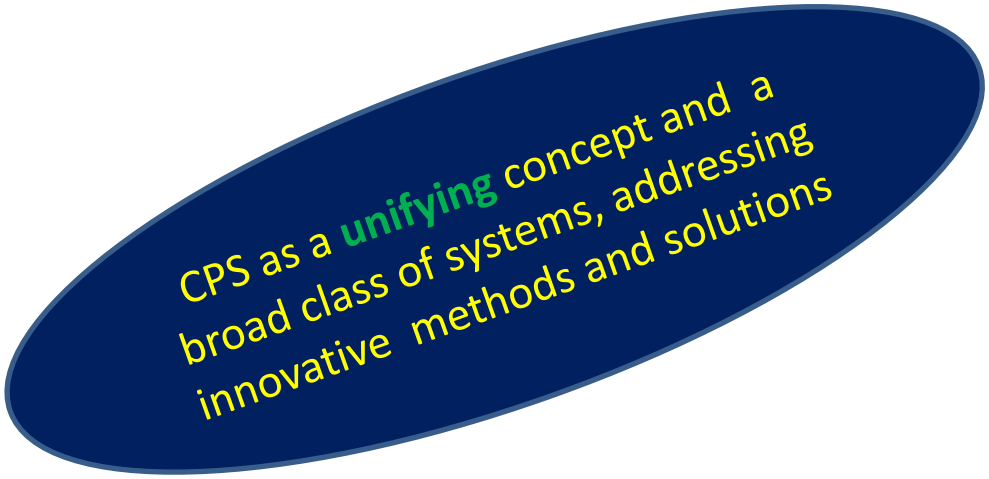
Horizon2020 (2014-2020)
Preliminary Information

H2020 main directions



- **Single program for the EC , EU27+**
- **Proposed funding: 80 Bi Euro/ 7 years, subject to approval (expected by end of 2012)**
- **To embrace R&D and Innovation actions**
- **H2020 content to be finalized in 2013**
- **Contractual facilitation for SMEs**
- **First calls for proposals expected early 2014**

CPS, or *CPS
Topic under consideration for the ICT part of of the forthcoming EU Horizon 2020 Programme



*CPS = advanced /networked/smart CPS
extending and **unifying** **technologies *and* communities**

Drivers and enablers for CPS

- **Energy**
- **Transportation**
- **Environment**
- **Health**
- **Dependability of systems**
- **Social and business networking and connectivity**
- **Innovation imperatives, competitiveness**
- **Other societal challenges and cost of living**
- **New world economic models**
- **other**

- **Advanced and low cost chips**
- **Computing, simulation tools**
- **New s/w & middleware**
- **Agent-based Architectures**

- **Novel sensors**
- **Robust /Efficient actuators**
- **Advanced controls (self*, robust)**

- **Dependable industrial networks**
- **Future Internet/Mobile nets**

- **HMI for all**

- **(e) Infrastructures**
- **other**

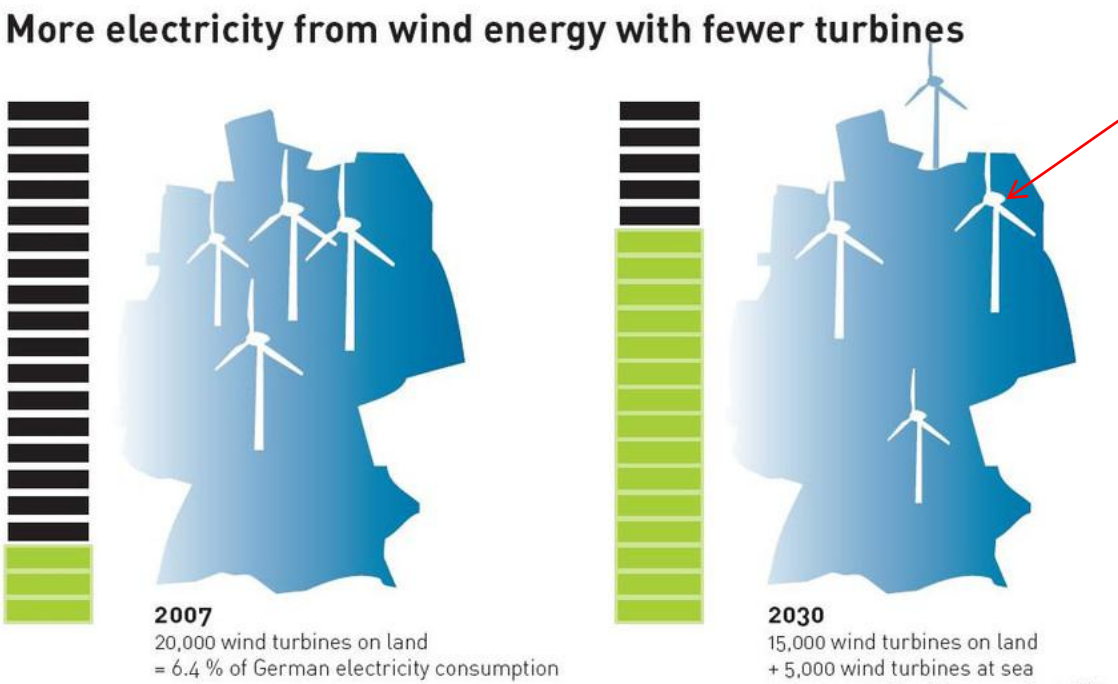
Ref: - *Prof Manfred Broy: "Engineering Cyber-Physical Systems" Lecture, Brussels, Oct 11, 2012*

- *NSF CPS 3rd Annual PI meeting , Research Agenda and international cooperation panels, National Harbor MD(USA), October 5, 2012 and previous work (see CPS V-O)*

- *Internal discussion papers, Computing, Systems of Systems, and CPS, DG CONNECT, EC, Brussels, Sept-Oct 2012*

- *Competitiveness week , Brussels Oct 2012 (see Ref. in Sect. 5)*

Example 1: New Energy needs strong CPS



More efficient wind turbines and systems, but not only (*)

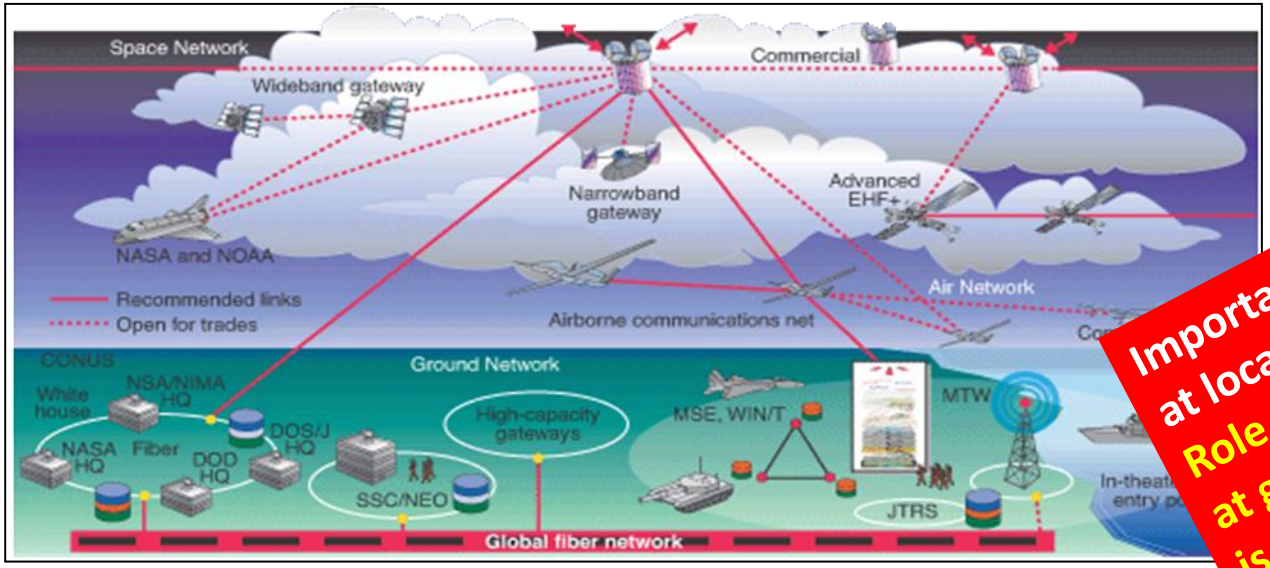
I. Mainly **Homogeneous** Systems

Control = Key factor at all levels

(*) and advances from Electrical Engineering (generators, transformers),wind turbine construction, blade shape & material , measurements ,control and optimization, tools for design , options exploration.

Example 2: CPS for designing, orchestrating, managing and executing very “complex “ engineering systems, or projects

II. Mainly **Heterogeneous** systems

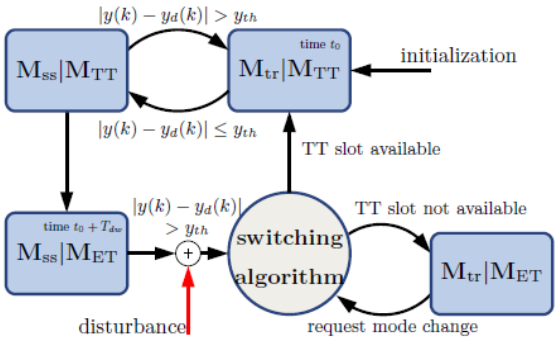


Important controls at local level. Role of Control at global level is a big challenge.

Source: (top: BOA, London 2012), (bottom : NASA and NOAA)

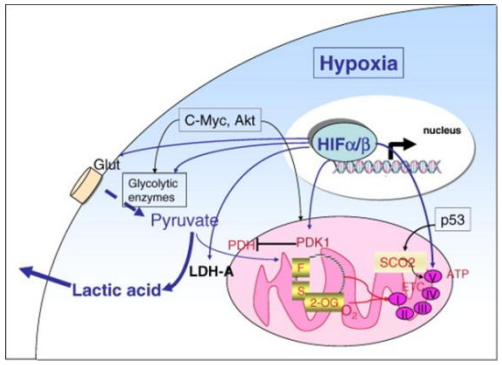
Example 3:The beauty of discontinuous systems and "switched-type " control for CPS

EC funding

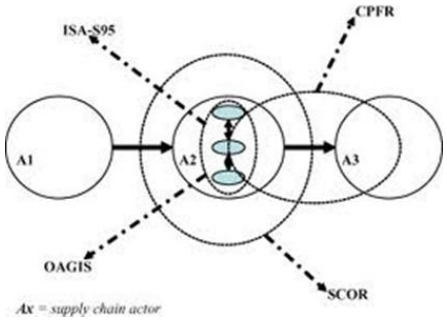


- **Hybrid systems ,Control, LMIs**
- Non-smooth systems
- Computational models
- Decision making support

Institute of Signaling, Developmental Biology and Cancer Research, University of Nice, FR

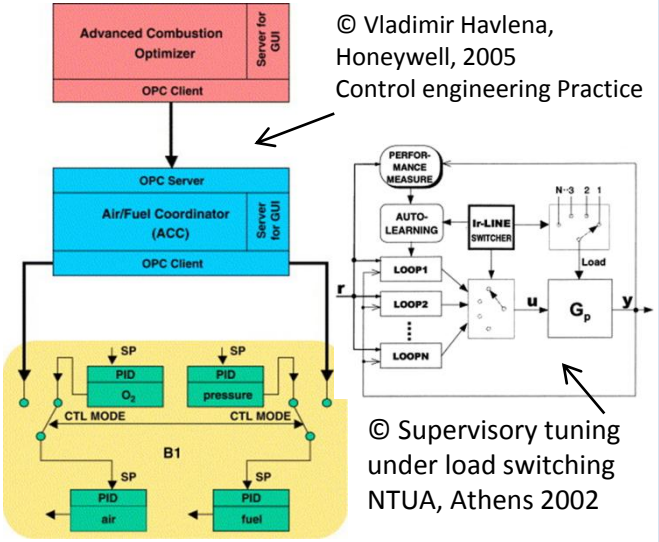


Switching in Biology systems



Source: Hans-Henrik Hvolby: Computers in industry, Dec 2010, Aalborg university

Switching in strategies and Business systems integration

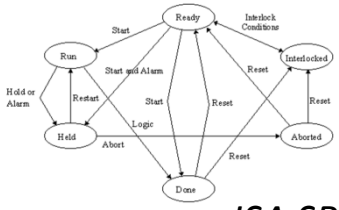


© Vladimir Havlena, Honeywell, 2005
Control engineering Practice

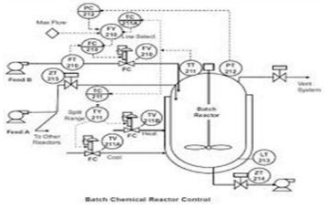
© Supervisory tuning under load switching NTUA, Athens 2002

Classic controllers switching

AB PLCs using InBatch © Wonderware



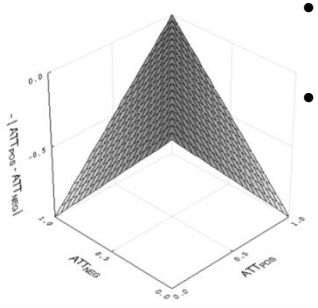
ISA SP88/95



Batch & sequential Control

A= (p+n)+ |p-n|/2

Griffin (1995)



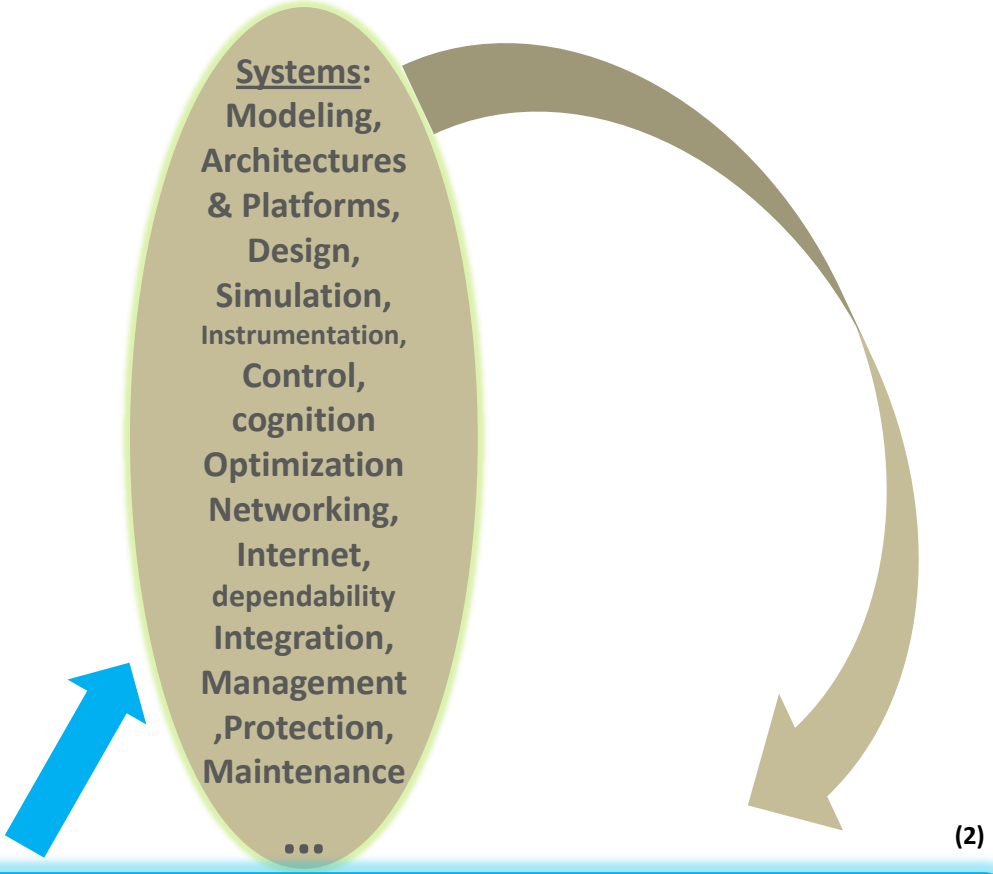
- *Human factors*
- *Decision making*

Psychology : non-smooth metric in evaluating "ambivalence" attitudes

For discussion

The computing continuum meets the systems continuum (partially bi-directional) (1)

Customization, Applications, Sectors, Societal Challenges, Economy, Growth, Failures, Concerns



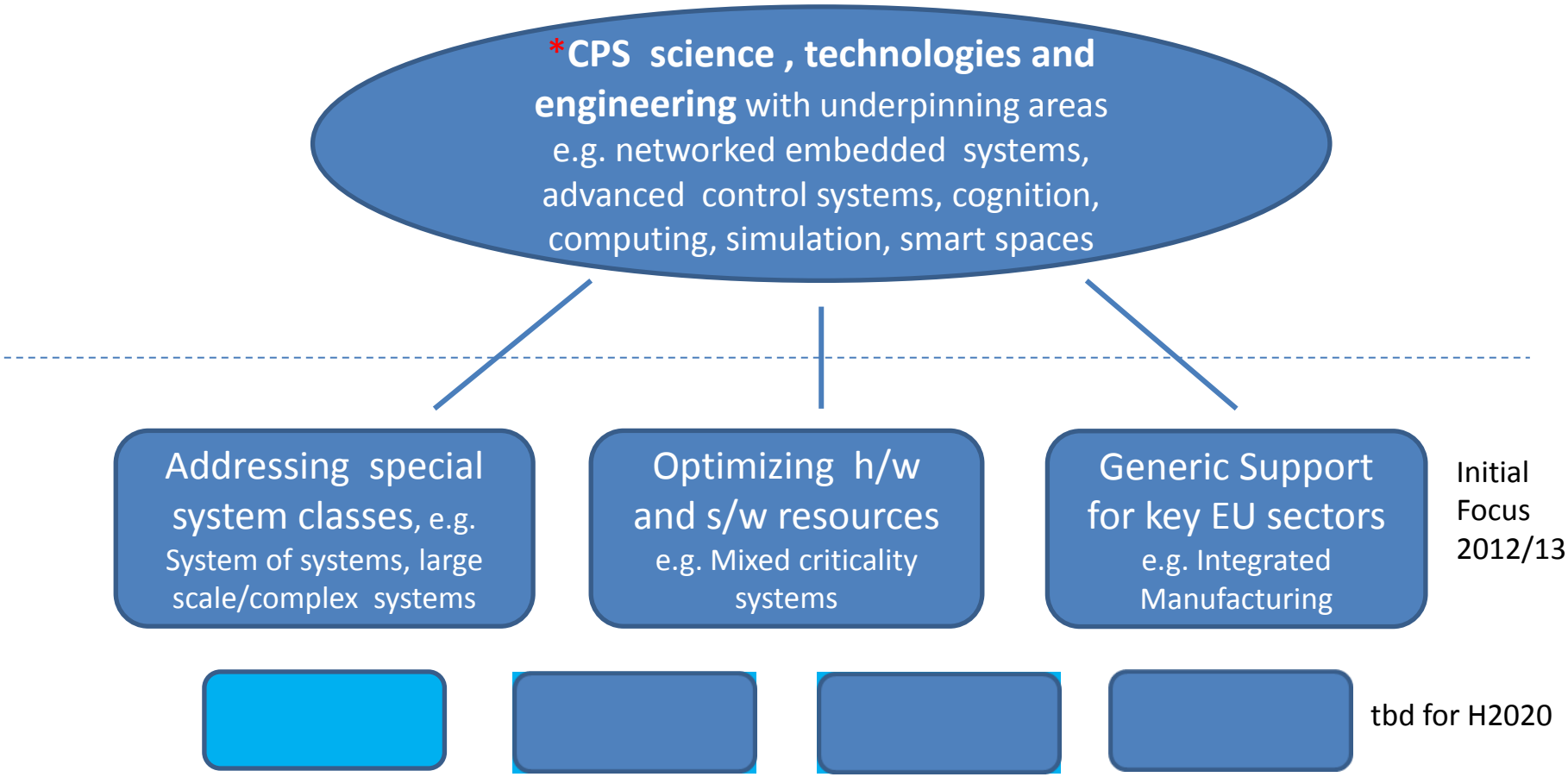
(2)

Computing: Embedded and general purpose chips & s/w e.g. FPGAs , DSPs ASICS ,GPUs; mutli-processors,…, multi/many cores, memories; high performance, virtualization,…; system architectures, RTOS; fault tolerance big data; cloud,…

(1) A.K, preliminary discussions /CONNECT–A3/ Oct 12, 2012, (2) The "computing continuum" in a recent DG CONNECT report (ML 2012, see references)

For discussion

In summary: A European Concept for *CPS (preliminary considerations)



Preliminary discussions Oct 2012

*CPS = advanced /networked/smart CPS

Other themes and areas under consideration/discussion for H2020 (*)

(based on on-going internal CONNECT and external discussions)

- Bridging the gap between <Embedded> and <HPC>
- Cognitive Control: synergies between <control> and <cognition>
- Hardware-Software-System co-design and cross-layer optimization
- Scalable MPC with concurrent Real-Time Optimization
- Coordinated control for networked dynamic systems
- Verification of distributed, multi/many core systems

Source: EC workshops, HYCON2 NoE, Position paper 2012, (*) Some may fall under a CPS theme

Control in the EC Programmes

Control is included for example in:

- several objectives of the ICT programme, e.g. ***Embedded systems & control***, Cognitive systems & Robotics, Energy efficiency, Transportation/Electro-mobility, Manufacturing,
- other non-ICT oriented EC programmes, such as NMP (e.g. adaptive production), Aeronautics, and Energy,
- Joint Undertakings e.g. SESAR (Air traffic), CLEAN SKY, ARTEMIS (Embedded computing) and H2 (Fuel cells)

At EC level :
Networking activities and Summer Schools by the Network of Excellence HYCON2 (2010-2014) and the BALCON project
(for the Western Balkan Countries, 2011-2013)

And 20+ funded ICT projects

Concerning the Systems and Control community, during the past 5-6 years:

- delivered new software tools and open source software,
- increased the volume of very good papers and books,
- achieved further acceptance and recognition by industry
- increased the industry-academia cooperation
- contributed to solving challenging engineering problems

Control as science, technology and engineering, but is only about 5-20% of total engineering

NMP= Nano-technologies, Materials, Production- Industrial technologies (EC FP7 programme)

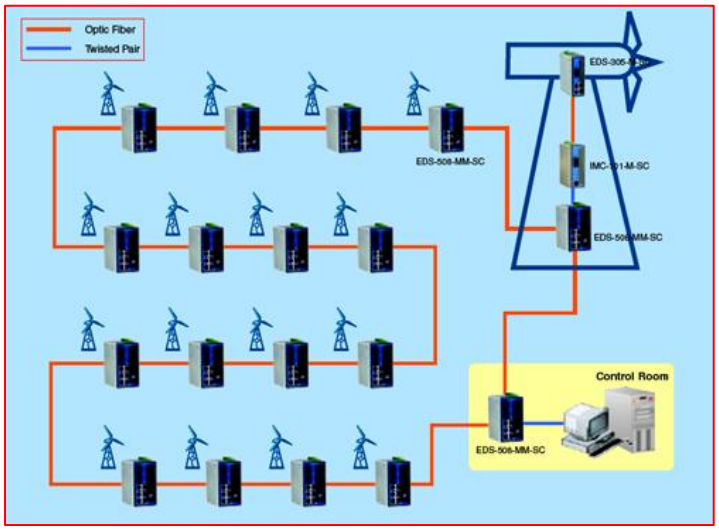
Based on EC/ICT experiences and some personal views (2000-2012

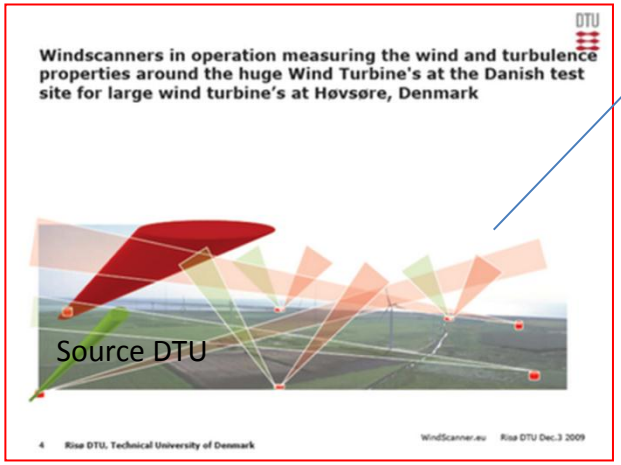
1. Cooperation with other communities

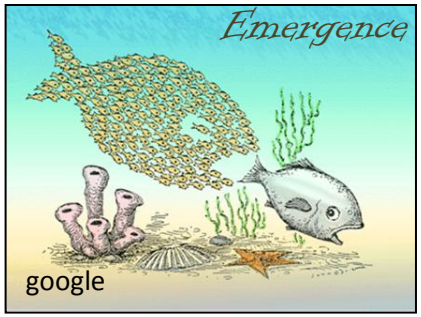
2. - Continue rigorous R&D
   - Deal with novel topics

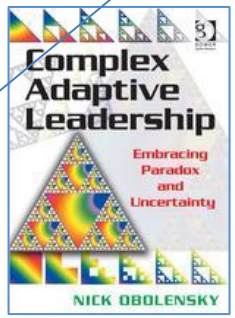
3. Exploit mature control methods and tools

4. Disseminate broadly







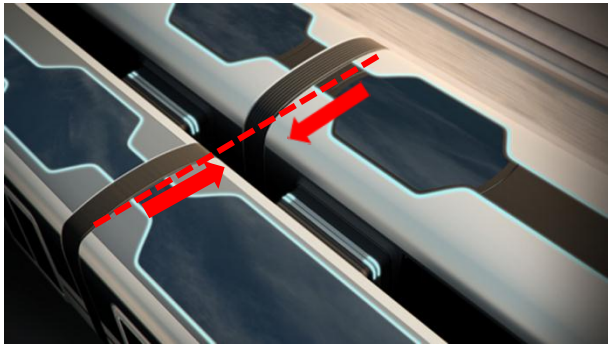


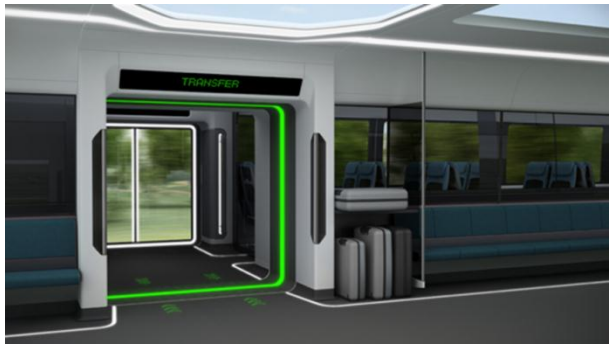
1. **Cooperation with other communities** for synergies:

- Control- CPS: new
- **control-sensing/ WSN**
- control -cognition,
- **control-optimization**,
- control-electronics
- control- computing,
- **control-software**
- control-complexity/management
- control- systems engineering
- control-internet and cloud.

2. A futuristic example: Moving platforms concept for non-stop rail-based transportation

Only possible if the trains travel in the same direction for some time !





Enormous challenge to build such coordinated/synchronized and reliable systems!

3. Exploit and commercialize mature advanced control methods

(e.g. MPC, distr. LQG/R, LMI, H_∞ , RT-optimization, multi-body dynamics models and control):

- Design methods and tools
  (from universities to industry and society)
- Create a “CATIA-type” modeling and design environment for control(?)
  (a kind of “SUPER” MATLAB/SIMULINK)
- Knowledge transfer across domains e.g. process control to automotive and vice-versa, automotive to aerospace !

From a smart tool -> to the market /product !

4. Disseminate broadly

- ***Success stories*** mainly when control/CPS is the only, or the main contributor to a method or solution
- ***Beyond the "standard" publications*** and dissemination channels of the established control communities
- ***Increase community presence*** in events of the neighboring disciplines (e.g. plenaries, publications)

How about a follow up of the IEEE CSS IoC Report (2011) ? Vol2 ?

Concluding thoughts

- ***Synergies between CPS and Control are promising:***
  - The EC is expected to embrace *CPS in H2020 aiming at innovations beyond "Networked Embedded & Control Systems".
  - It is the right time (now in 2012) for S&T reports, market data, foresights, industry position papers and ideas for H2020 topics.
- ***CPS challenges and expected impacts:*** *S&T&E e.g.*
  - *Scalability/performance of architectures and V&V&T for distributed, networked and many/multi-core systems in conjunction with control (co-)design*
  - *Ultra Fault Tolerant & Optimizing Real-Time Control addressing fault detection and recovery from "silicon" to high level*
  - ***Demonstrate benefits for industry and society within the next decade***
- ***Education:*** *Are we reaching a "saturation" of scientific efforts?*

  Need to motivate the younger generations into the systems fields (starting at high school level ! in all countries and regions.)

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But can the 16-18 years old ones do that ? Yes, if young boys and girls can solve IMO(*) problems they are able to do systems too!

*(see references)

Useful Links and references

- ARTEMIS: www.artemis-ju.eu
  http://cordis.europa.eu/fp7/ict/embedded-systems-engineering/documents/artemis-sra-2011.pdf
- ERC: http://erc.europa.eu
- EIT: http://eit.europa.eu, www.eitictlabs.eu
- EC, SoS reports, 2009 and 2012

ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/esd/workshop-report-v1-0_en.pdf

http://cordis.europa.eu/fp7/ict/embedded-systems- engineering/home_en.html

- EC MCS (Mixed Criticality Systems) new report 2012 in cordis
- EC Software for Advanced Computing Systems, Oct.2012 see cordis

http://cordis.europa.eu/fp7/ict/computing/documents/advanced_computing_ws_report.pdf

- EU Networks of Excellence (HYCON, HIPEAC, CONNET) and BALCON
- German CPS study “Integrated Research Cyber-Physical-Systems”
  www.acatech.de and workshop Berlin, 12 April 2012

http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Cyber-Physical-Systems/acatech_Agenda_CPS_20120410.pdf

- Prof. Shinji Hara: " Future Visions in Control", IFAC Japan Brochure , August 2011
  http://www.cyb.ipc.i.u-tokyo.ac.jp/files/FutureVision_JapanNMO.pdf
- IMO = International mathematical Olympiad for high schools: http://www.imo-official.org/general.aspx

Information portals about EU R&D and Innovation

More information:

- cordis.europa.eu/fp7/ict/computing/
- cordis.europa.eu/fp7/ict/embedded-systems-engineering
- www.ec.europa.eu/research/horizon2020
- www.artemis-ju.eu

http://ec.europa.eu/information_society/digital-agenda/actions/competitiveness-week/index_en.htm

http://www.knowledge4innovation.eu/EIS/SitePages/eis2012_Programme.aspx

Thank you for your attention!