BER-PHYSICAL SYSTEMS

ir: Alberto Sangiovanni-Vincentelli,

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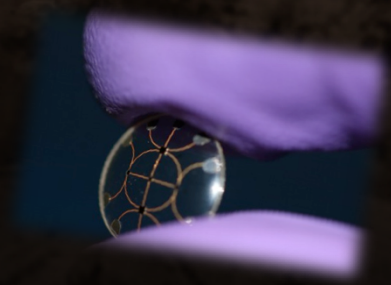
erkeley

akers
s A. Jacobson, United Technologies
Liu, Microsoft Research
Wristers, GLOBALFOUNDRIES

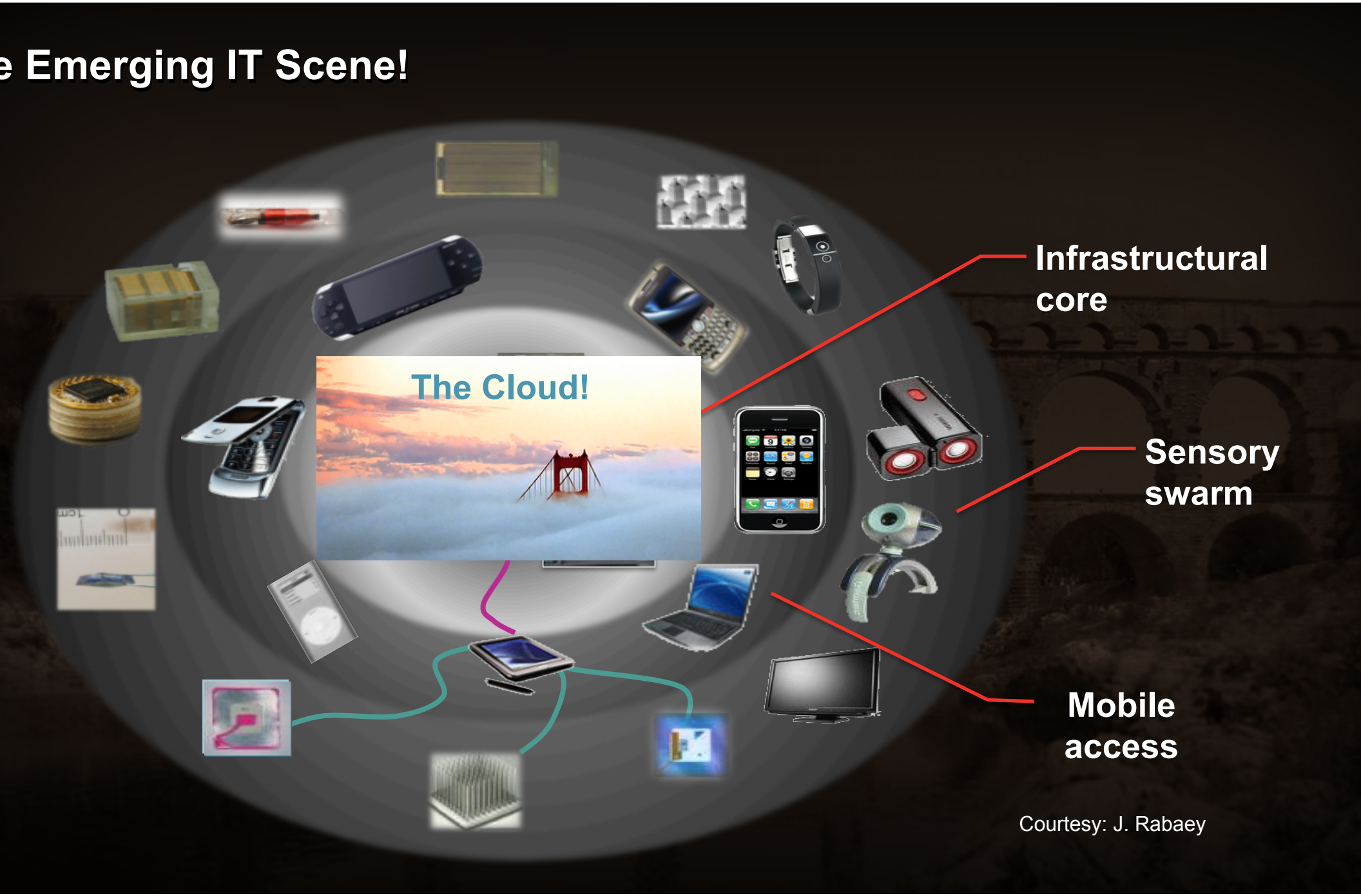
llenger
ward Lee, University of California at Ber



hnology Time Machine
um on Technologies
2020

5, 2012.
Germany

e Emerging IT Scene!



Courtesy: J. Rabaey

omputers and mobiles to disappear!

redictions: 7 trillions devices servicing 7 billion people!
1,000 devices per person by 2025

The Immersed Human

eal-life interaction between humans and cyberspace, enabled by enriched input and output
vices on and in the body and in the surrounding environment

ourtesy: J. Rabaey

M Smarter Planet Initiative:
mething profound is happening… CYBER PHYSICAL SYSTE

INSTRUMENTED

We now have the ability to easure, sense and see the xact condition of practically everything.

INTERCONNECTED

People, systems and objects can communicate and interact with each other in entirely new ways.

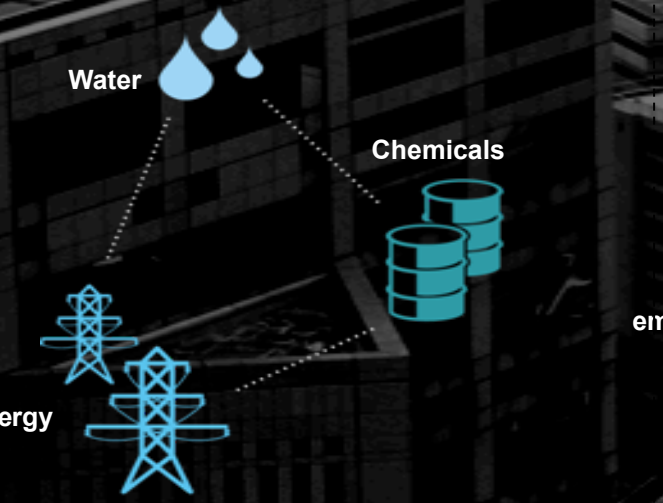
INTELLIGENT

We can respond to changes q and accurately, and get better results by predicting and optimizin for future events.

ntelligent systems that gather, synthesize and apply nformation will change the way entire industries operate.

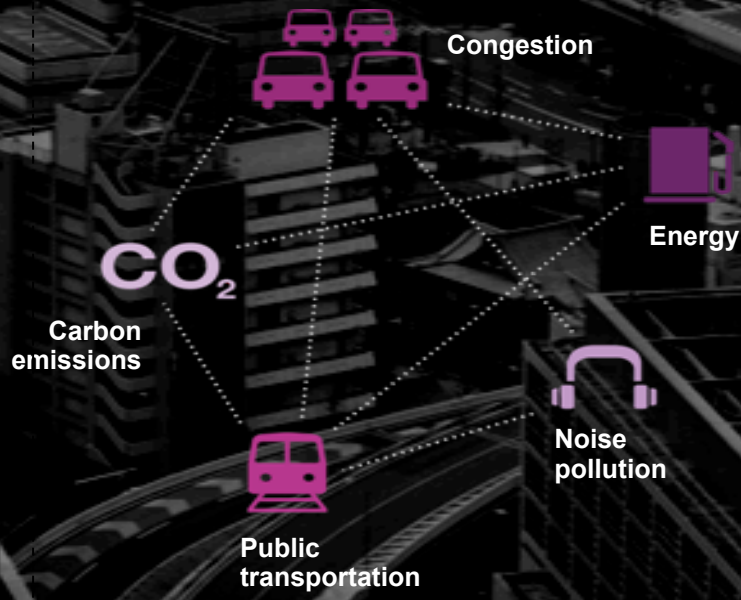
mart water

ly monitoring and management nologies to help optimize the lability, delivery, use, and quality ater as well as related systems uding energy and chemical tment.



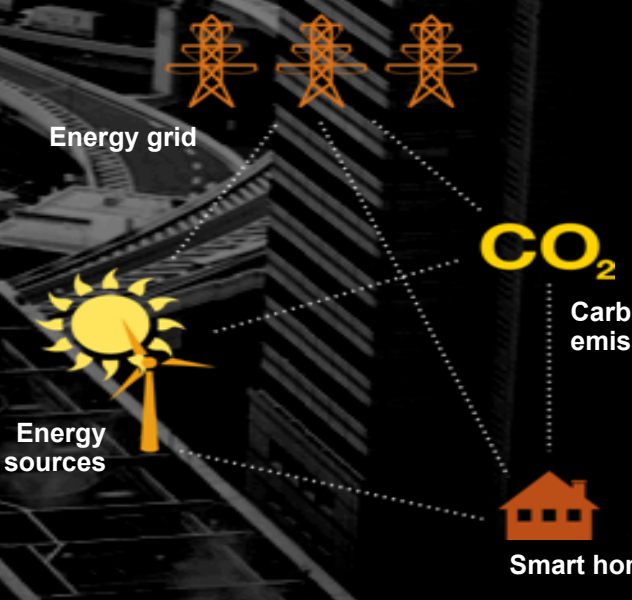
Smart traffic

Use real-time traffic prediction and dynamic tolling to reduce congestion and its byproducts while positively influencing related systems.



Smart energy

Analyze customer usage and provid customized products and services t help to boost efficiency from the so through the grid to the end user.



Vision 2025

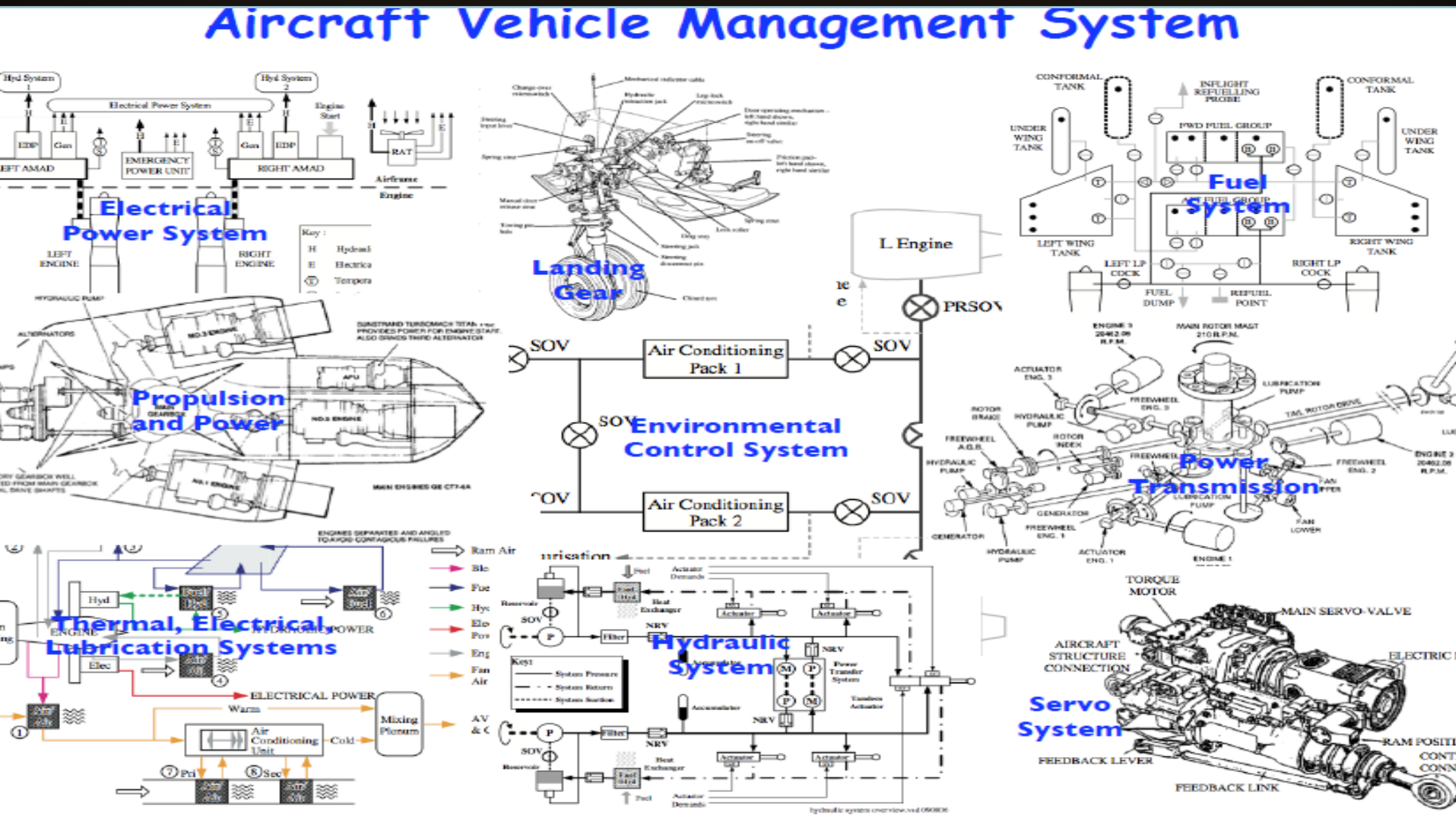
Every object will be smart

The Ensemble is the Function!

- Function determined by availability of **sensing, actuation, connectivity, computation, storage and energy**
- Collaborating to present unifying experiences or to fulfill common goals

humongous networked, distributed, adaptive, hierarchic hybrid control problem

An example of Cyber-Physical System (provided by UTC for MuSyC)



VMS Challenge Problem v1.0 (1Nov2010)

VMS Functions (replace flight engineer)

- Operate and monitor engine/aircraft systems ontrols and indicators;
- Perform engine starts, monitor run-up, flight peration and engine shutdown;
- Operate engine controls to provide desired fficiency and economy;
- Monitor engine instruments throughout period f operation;
- Control, monitor and regulate some or all ircraft systems: hydraulic, pneumatic, fuel, lectronic, air conditioning, pressurization; entilation; lubrication communication, avigation, radar, etc

VMS architecture (design exploration)

- Implement fully distributed system, with all ubsystems integrated across a networked ommunications interface

System Demonstrations

- **System startup**: From a cold start, turn all subsystems on and go into a normal operating mode
- **Transport mission**: pick up ground cargo usin winch from hovering configuration, transport car as swung load to drop-off location, deposit on ground, and depart from area
- **Landing operations**: support aircraft landing i easy (daylight, clear conditions), moderate (nighttime and/or rainy conditions) and difficult (dusty with icy weather) conditions
- **Safing mode**: perform operations that put vehi in safe operating mode, depending on condition vehicle
- **System diagnostics**: during normal operation log diagnostic data from all subsystems, w/ variable resolution

Where CPS Differs

The traditional embedded systems problem:

- Embedded system is the union of computing hardware and software immersed in a physical system it monitors and/or controls. The physical system is a given. The design problem is about the embedded system only.

Hybrid Systems

- Mixed discrete and continuous time systems

The CPS problem:

- Cyber-Physical Systems (CPS): **Orchestrating** networked computational resources with physical systems
- Co-design of physical system and controller
- Computation and networking integrated with physical processes. The technical problem is managing dynamics, time, and concurrency in **networked, distributed** computational + physical systems.

odeling Cyber-Physical Systems

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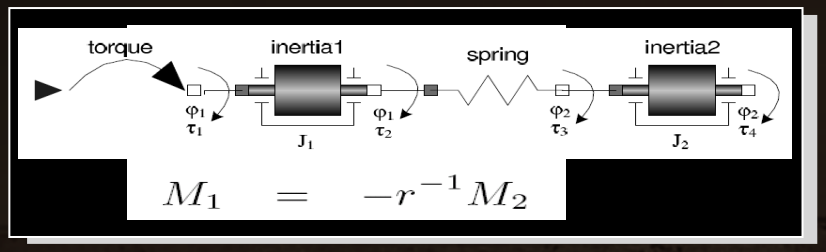

Equation-based model

Abstraction
"physical modeling"

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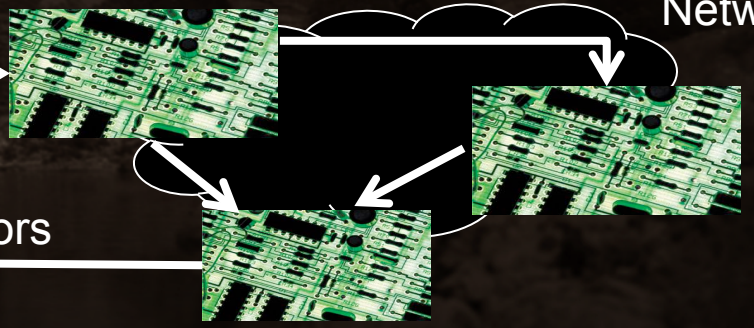
Physical system (the plant)

Sensors

Actuators



Embedded systems (computation)

Courtesy: D. Broman

odeling Cyber-Physical Systems

e, ASV: A framework for comparing models of computation, IEEE Trans. CAD, 1998)

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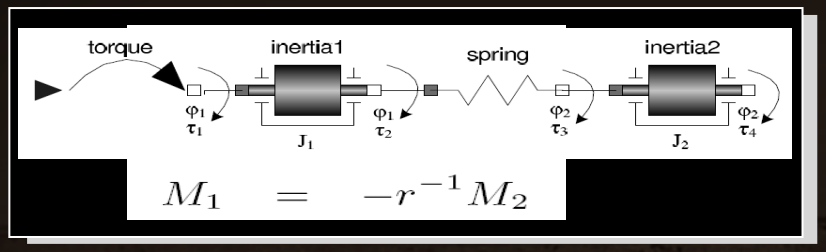
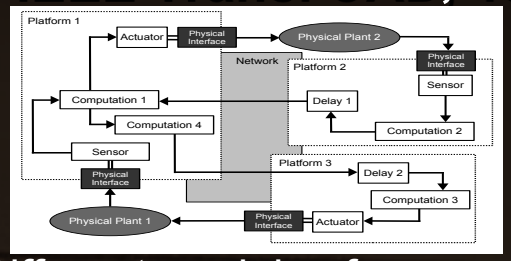


Equation-based model



Different models of computation

Abstraction
"physical modeling"

Concept of Time

C-coc

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Physical system (the plant)

Sensors

Actuators

Networ

Embedded systems (computation)

Courtesy: D. Broman

S modeling challenges for CPS

richer, systems view of computer science is needed. Ingredients include:

riching CS models with relevant physical/resource properties

- Physical, model-based computing
- Resource aware (time/energy) computing

rmal composition of multiple physics, models of computation, languages

- Composition of heterogeneous components

pact of cyber components on physical components and vice versa

- Physically-aware computing

Specific Challenges
(Derler, Lee, ASV, Proc. Of the IEEE, Jan. 2012)

Challenge 1: Models With Solver-Dependent, Nondeterminate, or Zeno Behavior

Challenge 2: Keeping Model Components Consistent

Challenge 3: Preventing Misconnected Model Components

Challenge 4: Modeling Interactions of Functionality and Implementation

Challenge 5: Modeling Distributed Behaviors

Challenge 6: System Heterogeneity

How Did we Cope with Complexity?

ASV, Corsi e Ricorsi: The EDA Story, IEEE Solid State Circuits Magazine, 2010)

General Principles

Traditionally complexity has been managed by two basic approaches:

- Decomposition: reduce the number of items to consider by breaking the design object into semi-independent parts (*divide et impera)*
- Abstraction: reduce the number of items by aggregating objects and by eliminating unnecessary details with respect to the goal at hand

Complexity is also managed by “construction”

- Constrain “artificially” the space (regular layout, synchronous designs)
- Start high in the abstraction layers and define a number of refinement steps that go from the initial description to the final implementation

The Dilemma

Raffaello Sanzio, The Athens School

Conclusion

We need a design and integration platform

- To deal with heterogeneity:
  - Where we can deal with Hardware and Software
  - Where we can mix digital and analog, cyber and physical
  - Where we can assemble internal and external IPs
  - Where we can work at different levels of abstraction
- To handle the design chain
- To support integration
  - Tool integration
  - IP integration
  - Team Integration

Platform-Based Design with Contracts can be the foundation for this platform

Final Words of Wisdom

The Way Forward for CPS

Everything is Connected: Society, Electronic and System Industry facing an array o
omplex problems from design to manufacturing involving complexity, power,
liability, re-configurability, integration….

Complexity is growing more rapidly than ever seen

Interactions among subsystems increasingly more difficult to predict

Pre-existing systems put to work to provide new services

Need work at all levels: Methodology, Modeling, Tools, Algorithms

Deep collaboration among

- Governments, industry, and research centers
- Different Disciplines : Control, Communication, Computer Science, Electrical Engineering , Mechanical Engineering, Civil Engineering, Chemistry, Biology....

References to our Work

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