INDUSTRIAL NEEDS AND ACADEMIC STATE OF THE ART AND BEYOND

Alberto Sangiovanni-Vincentelli

The Edgar L. and Harold H. Buttner Chair of EECS,
University of California at Berkeley

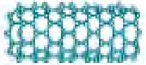
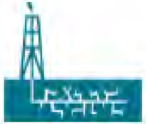
Co-founder, Member of the Board,
Cadence Design Systems

CyberPhysical Systems (CPS)

- *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.

CPS Relevance:
McKinsey’s Disruptive Technologies

Twelve potentially economically disruptive technologies

	**Mobile Internet**	Increasingly inexpensive and capable mobile computing devices and Internet connectivity
	**Automation of knowledge work**	Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments
	**The Internet of Things**	Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization
	**Cloud technology**	Use of computer hardware and software resources delivered over a network or the Internet, often as a service
	**Advanced robotics**	Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans
	**Autonomous and near-autonomous vehicles**	Vehicles that can navigate and operate with reduced or no human intervention
	**Next-generation genomics**	Fast, low-cost gene sequencing, advanced big data analytics, and synthetic biology (“writing” DNA)
	**Energy storage**	Devices or systems that store energy for later use, including batteries
	**3D printing**	Additive manufacturing techniques to create objects by printing layers of material based on digital models
	**Advanced materials**	Materials designed to have superior characteristics (e.g., strength, weight, conductivity) or functionality
	**Advanced oil and gas exploration and recovery**	Exploration and recovery techniques that make extraction of unconventional oil and gas economical
	**Renewable energy**	Generation of electricity from renewable sources with reduced harmful climate impact

Economic Potential

The Internet of Things	**300%** Increase in connected machine-to-machine devices over past 5 years **80–90%** Price decline in MEMS (microelectromechanical systems) sensors in past 5 years	**1 trillion** Things that could be connected to the Internet across industries such as manufacturing, health care, and mining **100 million** Global machine to machine (M2M) device connections across sectors like transportation, security, health care, and utilities	**$36 trillion** Operating costs of key affected industries (manufacturing, health care, and mining)
Cloud technology	**18 months** Time to double server performance per dollar **3x** Monthly cost of owning a server vs. renting in the cloud	**2 billion** Global users of cloud-based email services like Gmail, Yahoo, and Hotmail **80%** North American institutions hosting or planning to host critical applications on the cloud	**$1.7 trillion** GDP related to the Internet **$3 trillion** Enterprise IT spend
Advanced robotics	**75–85%** Lower price for Baxter[3] than a typical industrial robot **170%** Growth in sales of industrial robots, 2009–11	**320 million** Manufacturing workers, 12% of global workforce **250 million** Annual major surgeries	**$6 trillion** Manufacturing worker employment costs, 19% of global employment costs **$2–3 trillion** Cost of major surgeries
Autonomous and near-autonomous vehicles	**7** Miles driven by top-performing driverless car in 2004 DARPA Grand Challenge along a 150-mile route **1,540** Miles cumulatively driven by cars competing in 2005 Grand Challenge **300,000+** Miles driven by Google's autonomous cars with only 1 accident (which was human-caused)	**1 billion** Cars and trucks globally **450,000** Civilian, military, and general aviation aircraft in the world	**$4 trillion** Automobile industry revenue **$155 billion** Revenue from sales of civilian, military, and general aviation aircraft

UTC PRODUCTS

More integration…more software…
more complex operating modes

Google Strategy

CNET › Internet › Google closes $3.2 billion purchase of Nest

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The acquisition brings with it the Learning Thermostat and the Protect smoke and CO detector as Google looks to make its mark in the smart home.

by Lance Whitney @lancewhit / February 12, 2014 5:00 AM PST / Updated: February 12, 2014 5:19 AM PST

theguardian | TheObserver

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Google's drive into robotics should concern us all

The company's expansion into robotics was developed in tandem with the US military. Where will its power play stop?

John Naughton
The Observer, Sunday 29 December 2013

Google's robotic cars have about $150,000 in equipment including a $70,000 LIDAR (laser radar) system. The range finder mounted on the top is a Velodyne 64-beam laser. This laser allows the vehicle to generate a detailed 3D map of its environment. The car then takes these generated maps and combines them with high-resolution maps of the world, producing different types of data models that allow it to drive itself.

Google and Facebook

Google acquired Titan Aerospace, the drone startup that makes high-flying robots which was previously scoped by Facebook as a potential acquisition target, the WSJ reports.
The deal comes after Facebook disclosed purchase of U.K.-based Ascenta for its globe-spanning Internet plans.
Both Ascenta and Titan Aerospace are in the business of high altitude drones integral to blanketing the globe in cheap, omnipresent Internet connectivity to help bring remote areas online.
That's not all the Titan drones can help Google with, however. ***The company's robots also take high-quality images in real-time that could help with Maps initiatives, as well as contribute to things like "disaster relief" and addressing "deforestation,"….***

Apple

This week, years after that first sighting, Tesla announced plans for what it calls the "Gigafactory," a 10-million-square-foot plant for making car batteries. …But it's not just the prospect of a gasoline-free future that has sparked such excitement about the Gigafactory. The same basic lithium-ion tech that fuels Tesla's cars also runs most of today's other mobile gadgets, large and small. If Tesla really produces batteries at the scale it's promising, cars could become just one part of what the company does. **One day, Tesla could be a company that powers just about everything, from the phone in your pocket to the electrical grid itself.**

Earlier this month, as rumors swirled that Apple might want to buy Tesla, *San Francisco Chronicle* reported that **Tesla CEO Elon Musk had indeed met with the iPhone maker. Musk later confirmed that Tesla and Apple had talked, but he wouldn't say what about.**

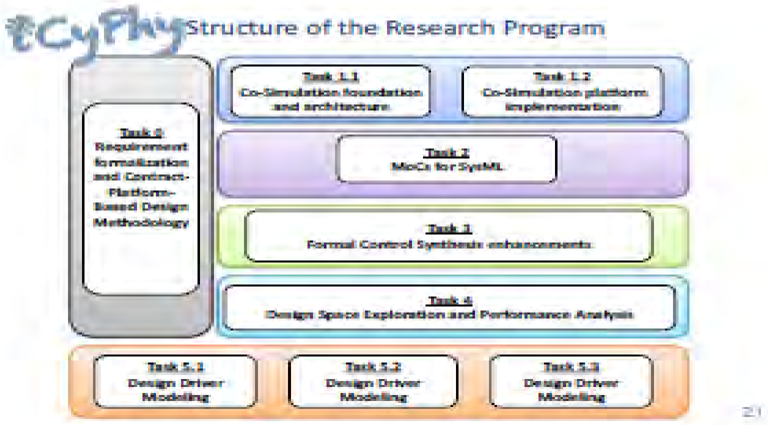
Needs for Industry of the Future

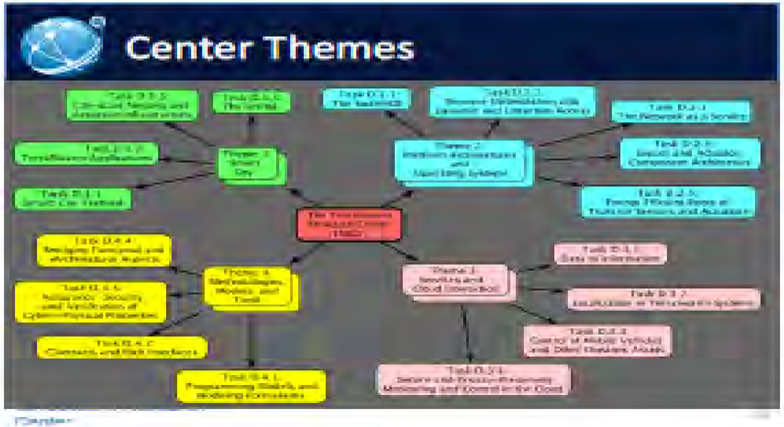
- MEMS, Analog and RF devices
- System Engineering
- System Integration
- Multi-physics systems
- Scalable computing architectures
- Networked-oriented operating

- Security/privacy
- User interfaces
- Collaboration applications
- Intelligent learning systems
- Program verification
- Methodologies for HW/SW design/evaluation

The single most serious problem in industry today is to find PEOPLE with the right expertise!

INVESTMENTS





Confluence of UTC's Needs and UConn's Strategic Initiatives

United Technologies

UTC Products & Needs

- More Integration, More Software and More Complex Operating Modes
- Shorter Development Cycles
- Reduce Design Flow Burden on Integration & Testing
- Need for Trained Systems Engineers

UTC–UConn Partnership

- UTC's Systems Leadership
- UConn's Strong SE Core
- Exceptional Investments in UConn (NextGen, Tech Park, P&W Additive Manufacturing Institute, CHASE, CEI, COE in Advanced Materials)
- Favorable Proximity
- 85-Yr Rich Partnership

Design “Practice”

TEACH DESIGN SCIENCE: Principles not Techniques

The Challenges of CPS Design and…Teaching!

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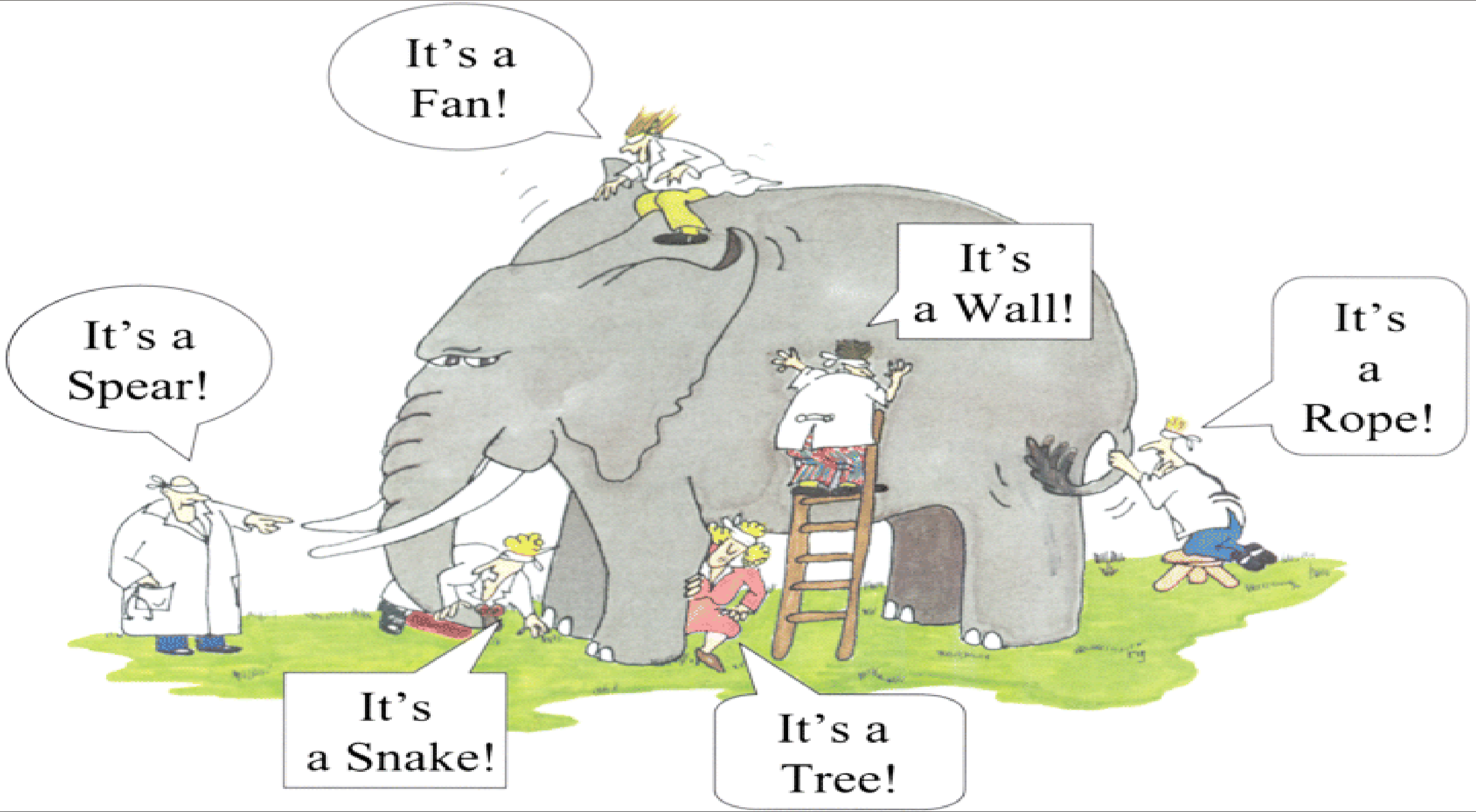
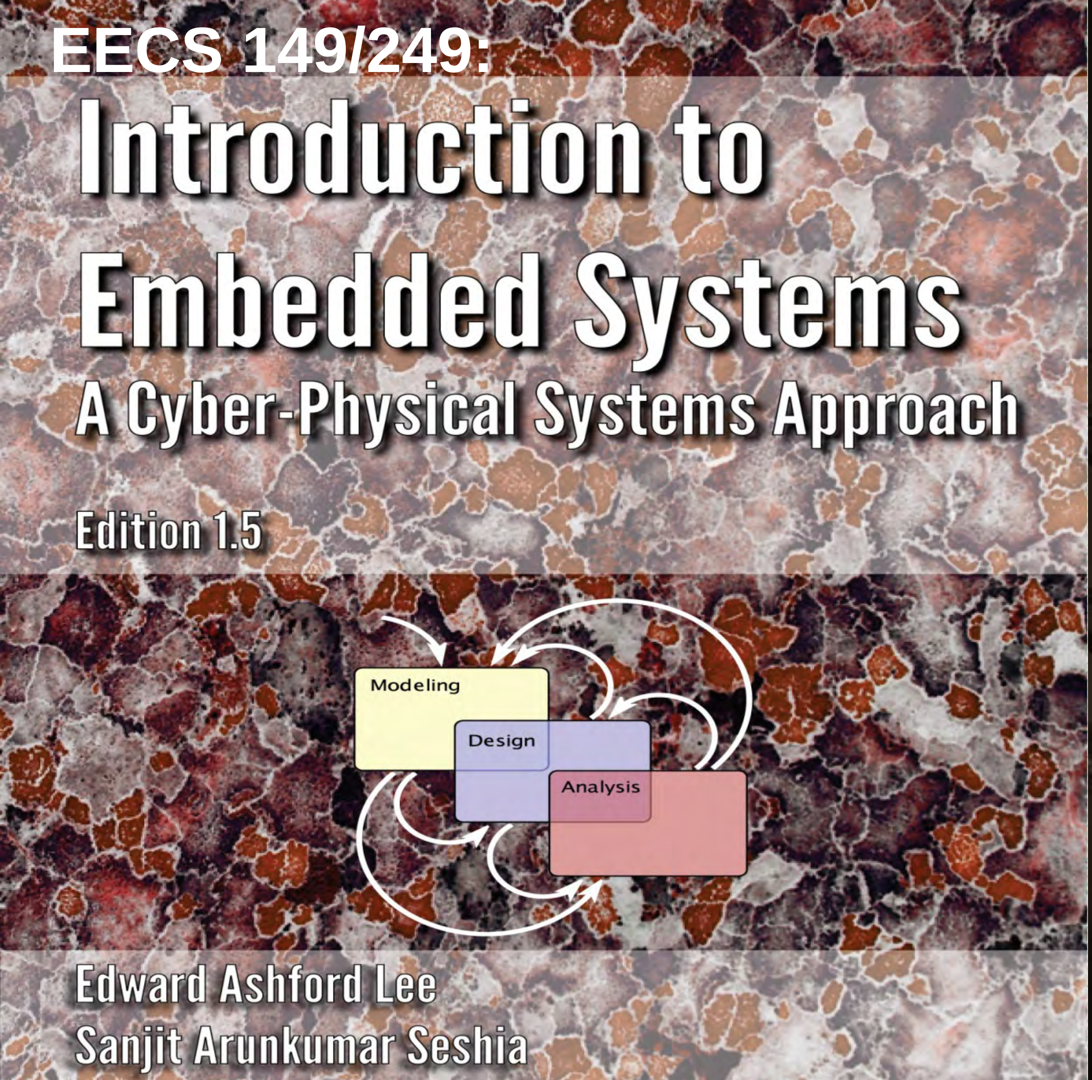


EECS 149/249:



Your textbook, written for this course, strives to identify and introduce the *durable intellectual ideas* of embedded systems as a technology and as a subject of study. The emphasis is on modeling, design, and analysis of cyber-physical systems, which integrate computing, networking, and physical processes.

Use edition 1.5, a prerelease of the Second Edition!

EE249: "Embedded System Design with CPS Emphasis"

A graduate 4 unit system design course:

- Emphasis on understanding of system design
  - the basic mathematical models representing system behavior independent of implementation
  - Implementation as choice of architecture
  - Architecture as platform
  - Mapping of behavior into architecture as an exercise in design exploration
  - Software and hardware seen uniformly

Difficulties in teaching CPS

- People who have «physical» competence (mechanical, civil, chemical, electrical engineering) should learn abstractions, models of computation and software architecture
- People who are computer «scientist» should learn continuous time systems (PDEs, ODEs, discrteization, sampling, controls...) MUCH MORE DIFFICULT

The Emerging IT Scene!

Courtesy: J. Rabaey

Computers and mobiles to disappear!

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

The Immersed Human

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

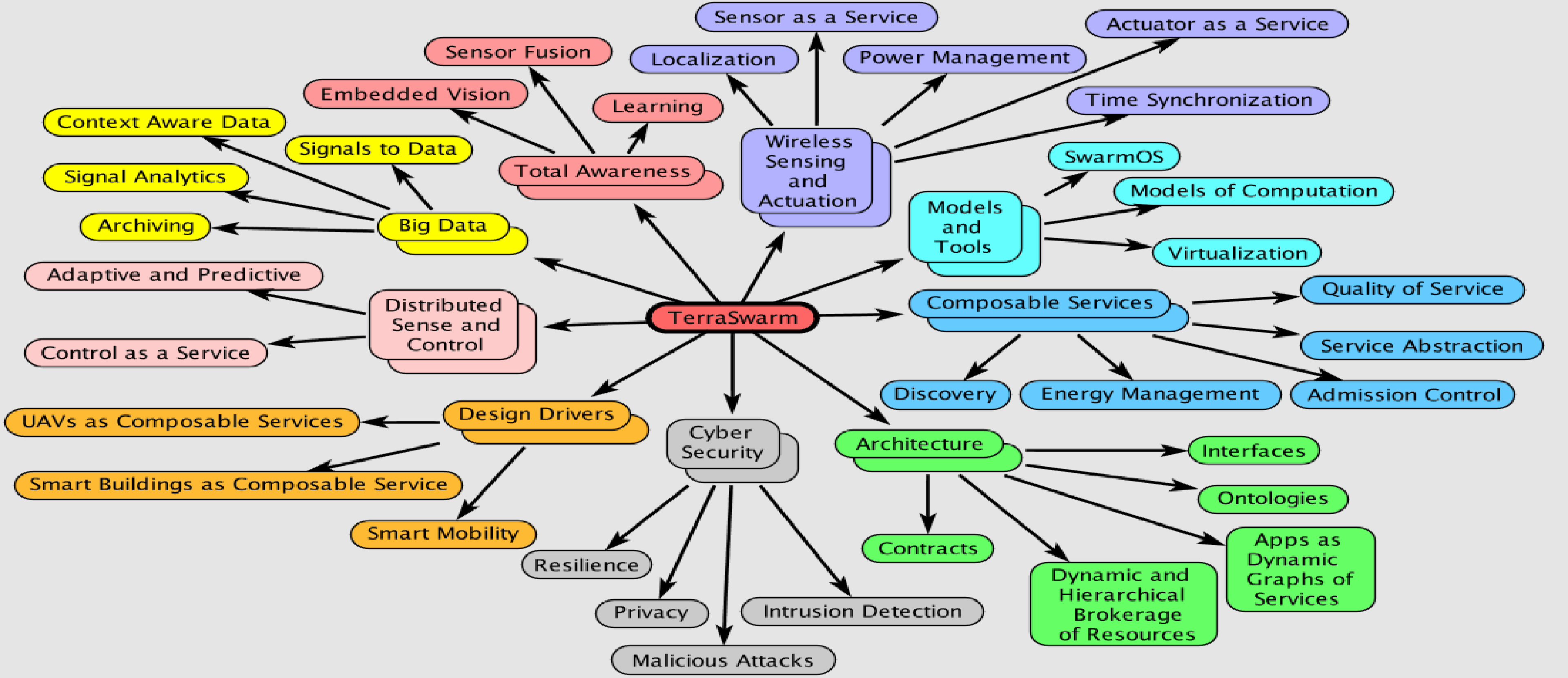
Courtesy: J. Rabaey

Vision 2025

- Integrated components will be approaching molecular limits and/or may cover complete walls
- 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

A humongous networked, distributed, adaptive, hierarchical, hybrid control problem

The Problem Space (TerraSwarm)



Summary

- Education in such a complex world must come from deep understanding of basic issues
- Do not mistake techniques for principles!
- Ad hoc engineering solutions should be avoided at all costs
- Balance of foundations and experience

Dr. Right