



**Предизвикателства и възможности на  
кибер - физическите системи  
с човек във веригата**

Challenges and Opportunities in CPS  
with Human in the Loop

XV КОНФЕРЕНЦИЯ АСТЕЛ `2017



Системи, които свързват кибер света на информационните и комуникационните технологии с физическия свят се наричат Кибер - Физически Системи.

Кибер - Физическите Системи системи тясно интегрират комуникационна, компютърна техника и управление с физическия свят и околната среда, в резултат, на което в последните няколко години те се считат гранична наука, покриваща най-новите хипотези в научния свят.



Областта на приложение на Кибер – Физическите Системи включва медицински системи, асистиращи системи, контрол на движението и безопасността, автономни автомобилни системи, контрол на процесите, икономия на енергия, разпределена роботика, оръжейни системи, разпределено управление и контрол, производство, критичната инфраструктура, интелигентни структури, био-системи , комуникационни системи и т.н.



# Challenges and Opportunities in CPS with Human in the Loop

(Представена на „Global Wireless Summit 2016“)



**GWS 2016**  
Global Wireless Summit

**Aarhus, Denmark**  
November 27-30, 2016



# The Next Computing Revolution

- **Mainframe computing (60's – 70's)**

Large computers to execute big data processing applications

- **Desktop computing & Internet (80's – 90's)**

One computer at every desk to do business/personal activities

- **Ubiquitous computing (00's)**

Numerous computing devices in every place/person

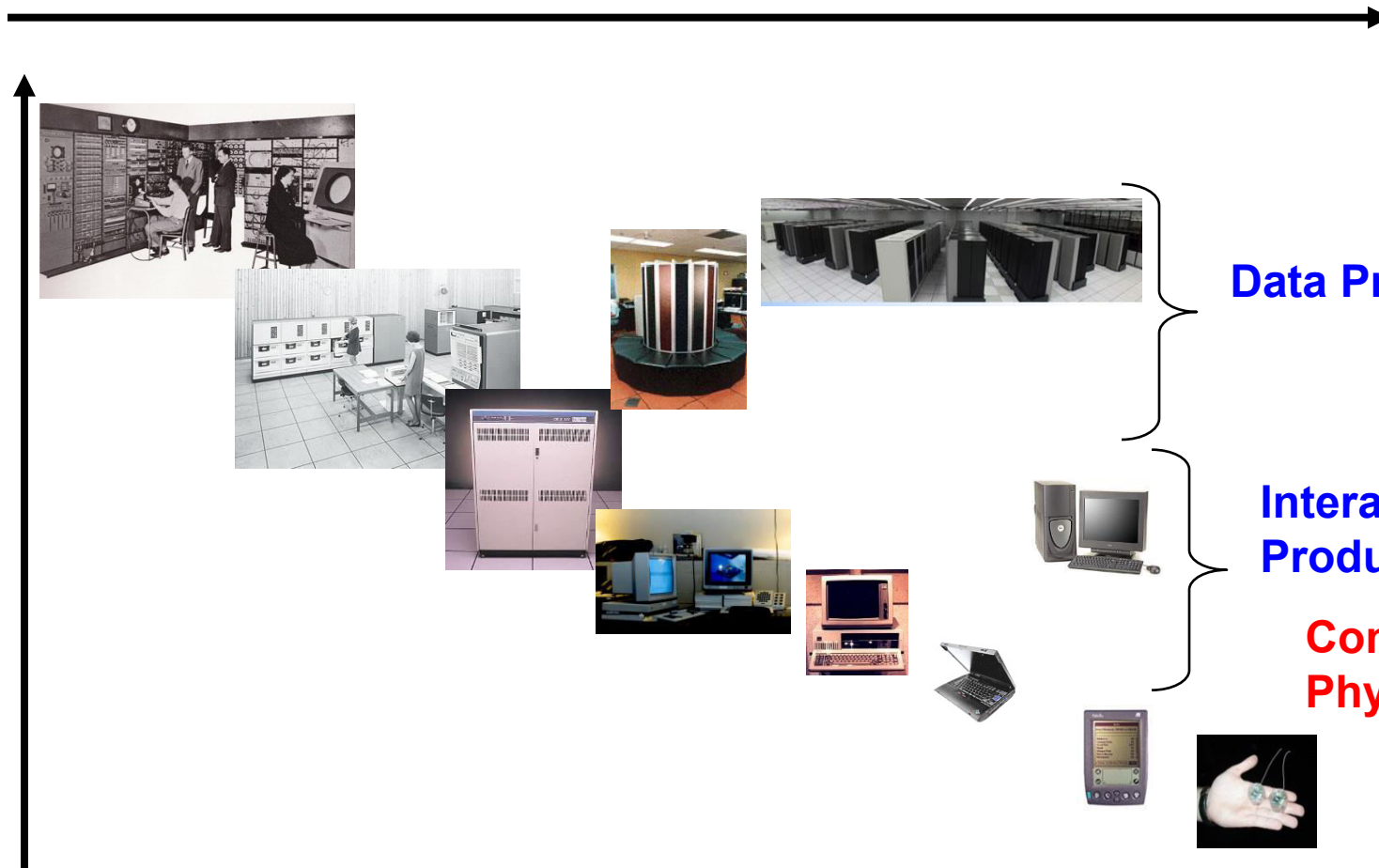
Millions for desktops vs. billions for embedded processors

- **Cyber Physical Systems (10's)**



1960      1970      1980      1990      2000      2010

log (people per computer)





# What are Cyber Physical Systems?

- **Systems that “bridge the cyber-world of computing and communications with the physical world are referred to as Cyber-Physical Systems (CPS)”**
- **CPS is a system featuring a tight combination of, and coordination between, the system’s computational and physical elements.**
- **CPS uses computations and communication deeply embedded in and interacting with physical processes to add new capabilities to physical system.**
- **Convergence of computation, communication, and control**



# Why Cyber Physical Systems?







- **Embedded computers allow us to add capabilities to physical systems.**
- **By merging computing and communication with physical processes, CPS brings many benefits:**
  - Safer and more efficient systems
  - Reduced cost of building and operating systems
  - Formation of complex systems that provide new capabilities
- **Technological and Economic Drivers**
  - The decreasing cost of computation, networking, and sensing provides the economic motivation.
  - Ubiquitous computers and communication enable national or global scale CPSs. (eg. national power grid, national transportation network)





# CPS creates Opportunities

The potential of CPS is boosted by several recent trends in wireless communications; low cost, low-power, high-capacity, small form-factor computing devices and increased-capability sensors, continuing improvements in energy distribution, alternative energy sources and energy harvesting .

Sectors	Opportunities	
<i>Transportation</i>	Aircraft that fly faster and further on less energy. Air traffic control systems that make more efficient use of airspace. Automobiles that are more capable and safer but use less energy.	
<i>Defense</i>	More capable defense systems; defense systems that make better use of networked fleets of autonomous vehicles.	
<i>Energy and Industrial Automation</i>	New and renewable energy sources. Homes, office, buildings and vehicles that are more energy efficient and cheaper to operate.	
<i>Health and Biomedical</i>	In-home healthcare delivery. More capable biomedical devices for measuring health. New prosthetics for use within and outside the body. Networked biomedical systems that increase automation and extend the biomedical device beyond the body.	
<i>Agriculture</i>	Energy efficient technologies. Increased automation. Closed-loop bioengineering processes. Resource and environmental impact optimization. Improved safety of food products.	
<i>Critical Infrastructure</i>	Highway systems that allow traffic to become denser while also operating more safely. A national power grid that is more reliable and efficient.	



# What are the requirements?

CPSs operate in dynamic contexts and thus have to:

- handle uncertainty that results from phenomena such as interference and noise, abnormal behavior, rare events, evolving structure, etc.
- Include humans in the loop of the CPS thus adding uncertainty.
- cope with noisy and heterogeneous data, to offer robust performance over often unreliable wireless and open communication networks,
- operate safely, securely, and efficiently.

**All this in real-time as they interact with the physical world.**

# Challenge: Human in the Loop



- CPS with Human-in-the-loop is a system that must take human response into consideration and human presence and behavior becomes a key part of the system instead.
- It is essential to develop and integrate reliable and accurate human behavior modeling techniques that attempt to learn and predict human behavior.



# Human-system interaction

*Conventional Control System Design assumes only information feedback. CPS will include physical feedback.*

## aircraft

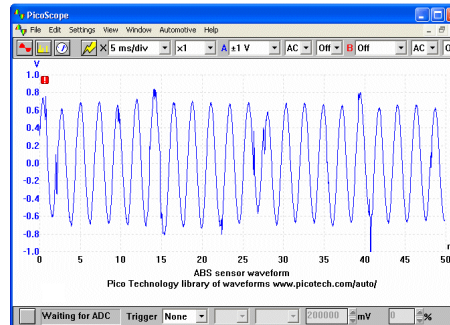
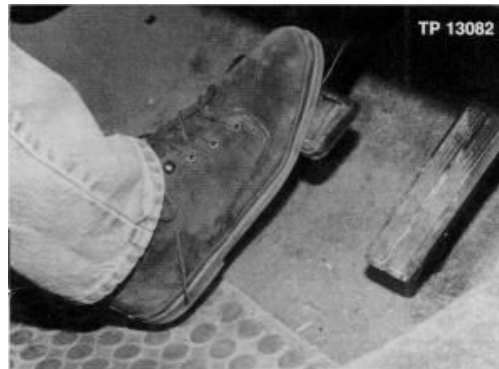
Boeing 777



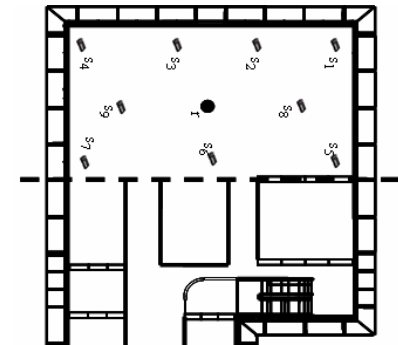
Airbus 380



## ABS



## building control?







# Human-system interaction

*Conventional Control System Design assumes only information feedback. CPS will include physical feedback.*

## aircraft

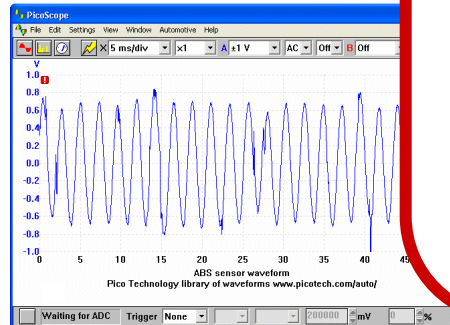
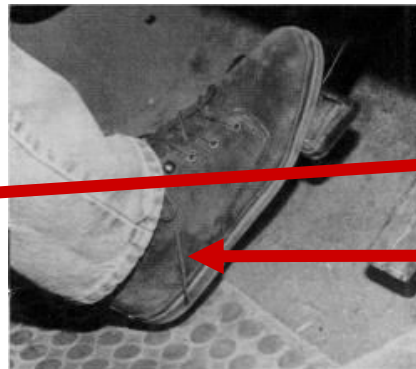
Boeing 777



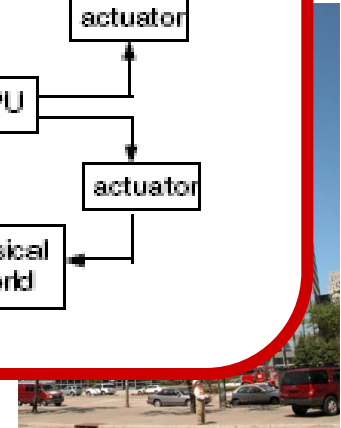
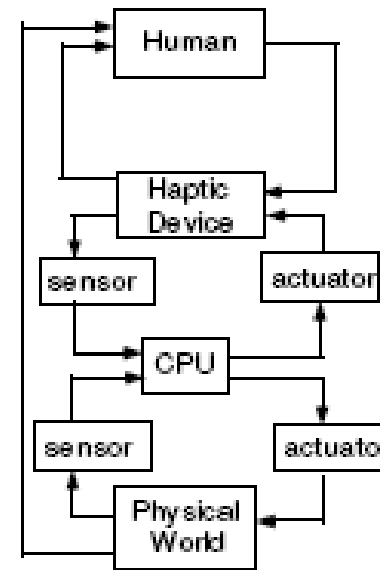
Airbus 380



## ABS



## Haptic systems design





# Human-system interaction

*Conventional Control System Design assumes only information feedback. CPS will include physical feedback.*

*aircraft*

*Boeing 777*

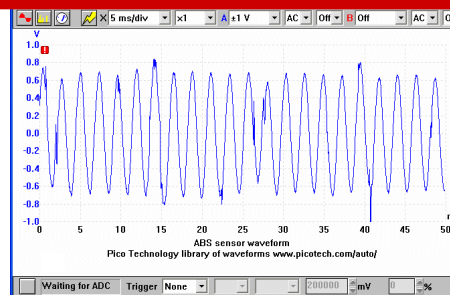
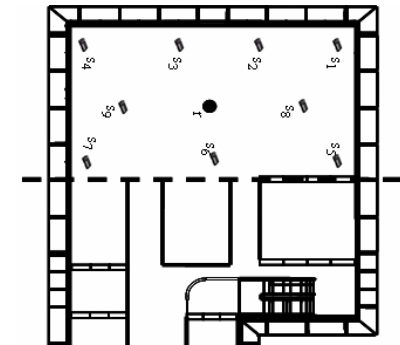


*Airbus 380*



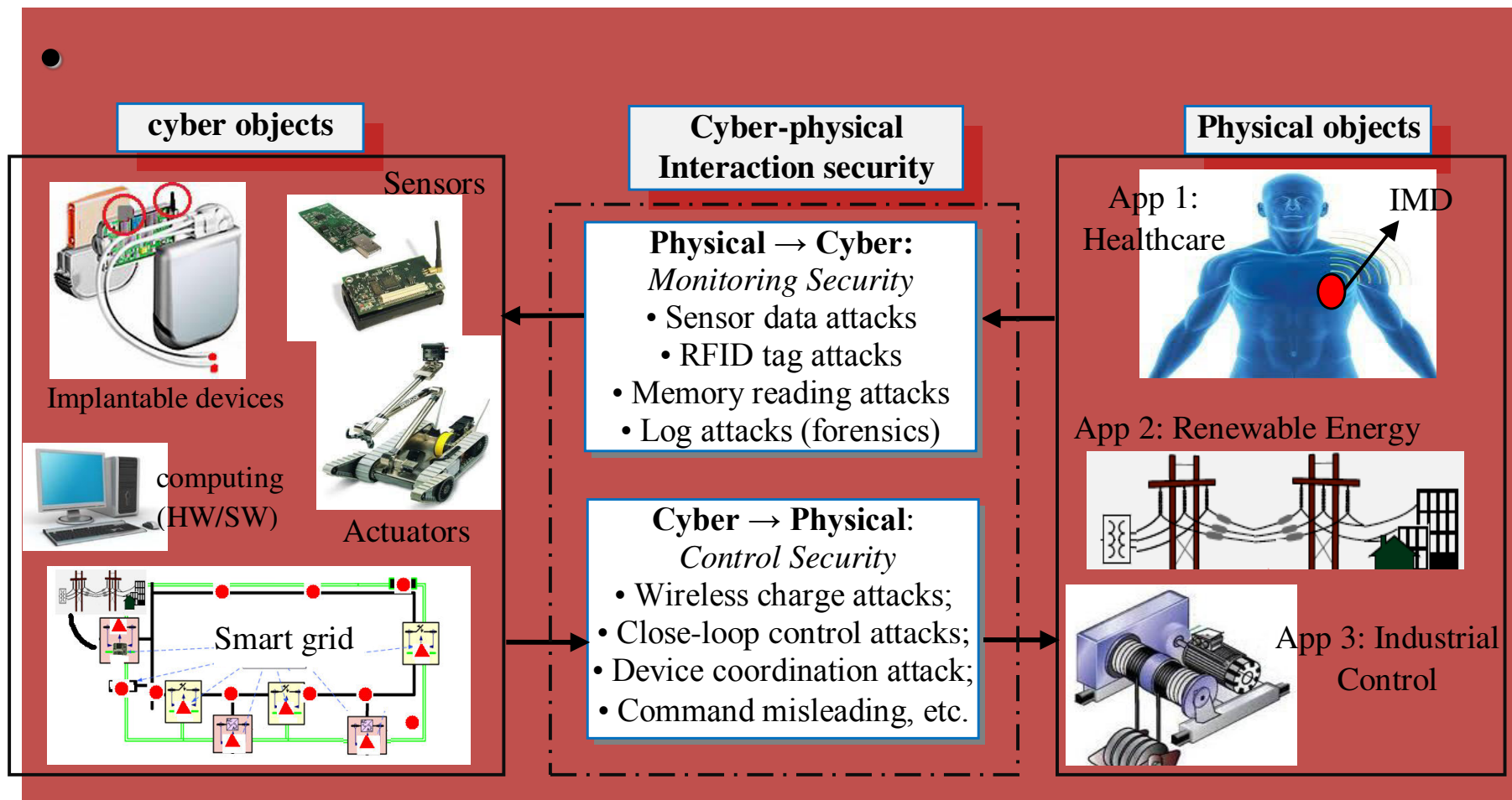
Integrate human behavior into the control loop (e.g., make it uncomfortable so they will open the windows)

*building control?*





# Challenge: Security



Cyber-Physical Systems (CPS): Security Perspective



# Example: Cyber-physical transportation systems

- In 2005, 30 – 90 processors per car

Engine control, Break system, Airbag deployment system, Windshield wiper, Door locks, Entertainment system

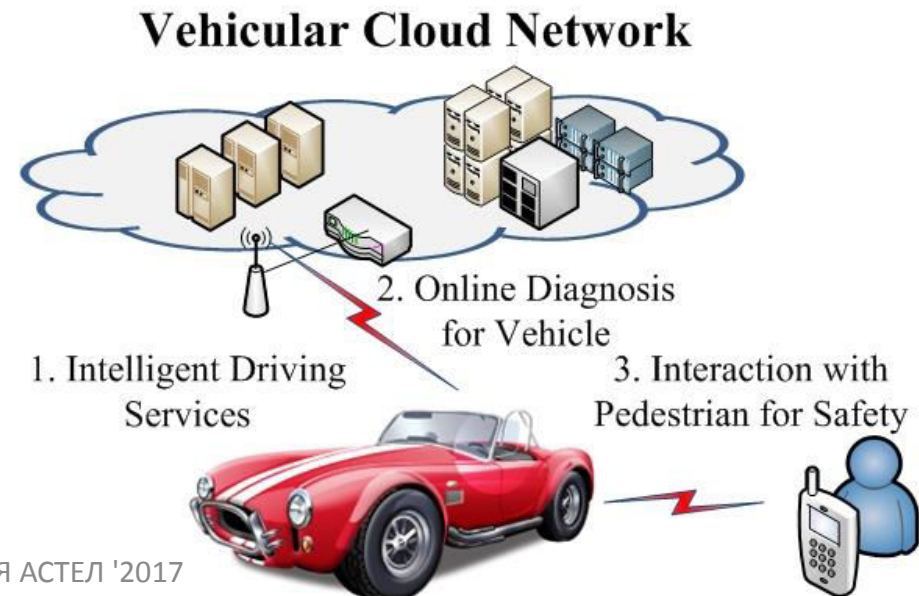
- Cars are sensors and actuators in V2V networks

Active networked safety alerts, Autonomous navigation

- Future Transportation Systems

Incorporate both single person and mass transportation vehicles, air and ground transportations.

Achieve efficiency, safety, stability using real-time control and optimization.







# Example: Health Care and Medicine

- National Health Information Network, Electronic Patient Record

- Home care: monitoring and control

Pulse oximeters, blood glucose monitors, infusion pumps, accelerometers, ...

- Operating Room of the Future

Closed loop monitoring and control; multiple treatment stations, plug and play devices; robotic microsurgery

System coordination challenge

- Progress in bioinformatics: gene, protein expression, systems biology, disease dynamics, control mechanisms





# Long-Term CPS Goal

- Transform how we interact with the physical world just like the internet transformed how we interact with one another.
  - Convergence of embedded systems, control theory, hybrid systems, microcontrollers, sensors, actuators, wireless networks, wide area networks, distributed systems, operating systems, advances in structures, ...

Seek scientific foundations and technologies to integrate cyber-concepts with the dynamics of physical and engineered systems.



**БЛАГОДАРЯ !**