Introduction to Cyber Physical System

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References

- CIS 441/541: Embedded Software for Life- Critical CPS/ IoT Applications

- Insup Lee

- Department of Computer and Information Science School of Engineering and Applied Science University of Pennsylvania

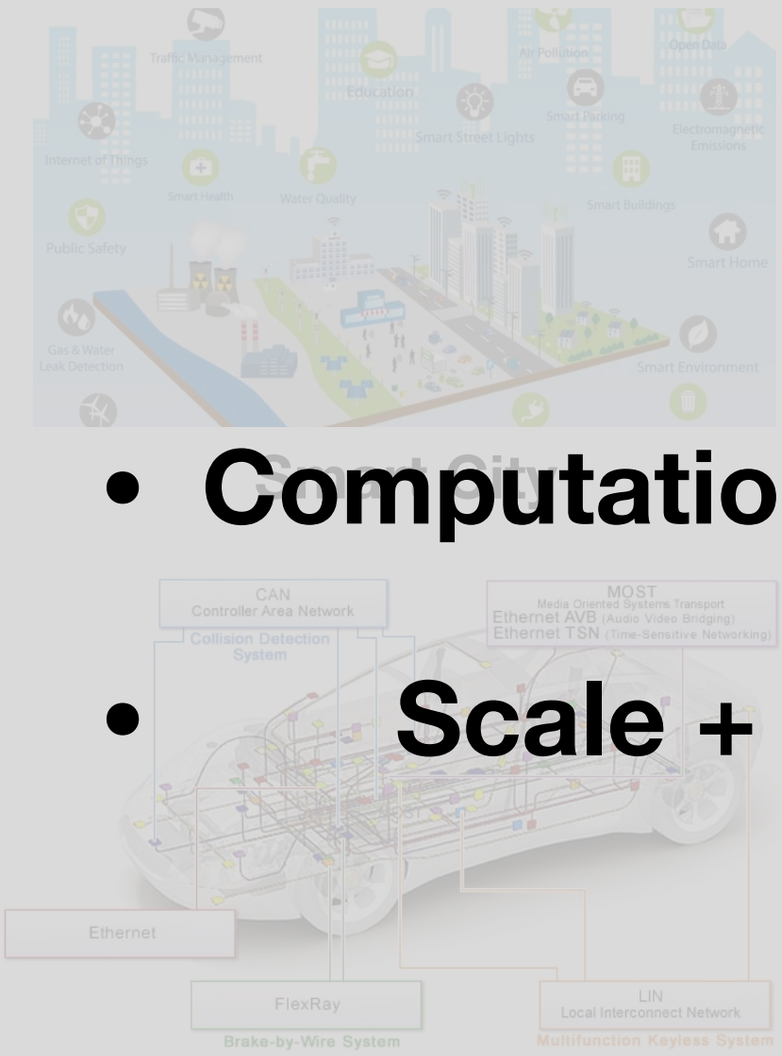
Computing Revolution History

- Mainframe computing (60’s-70’s)
    - Large computers to execute big data processing applications
- Desktop computing & LAN (80’s)
    - One computer at every desk to do business/personal activities
- Internet and WWW (90’s)
- Ubiquitous computing (00’s)
    - Numerous computing devices in every place/person – Information anywhere, anytime

Next Revolution

- Cyber Physical Systems (CPS) and Internet of Things (IoT)

Cyber-Physical Systems



- **Computation + Physical world + Networking**
- **Scale + Diversity + Ubiquity + Safety**

Vehicle Systems

Smart Grid

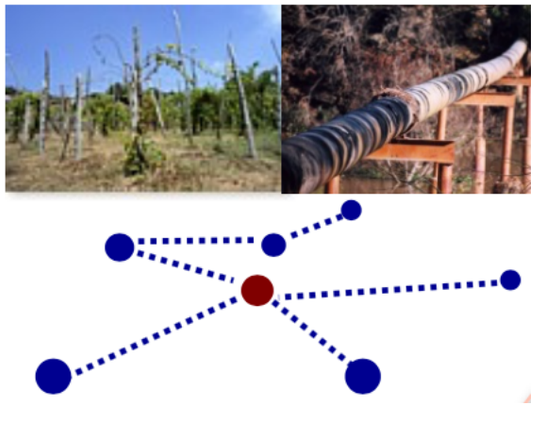
Aircraft

Trend 1:
Data/Device Proliferation

Embedded Everywhere

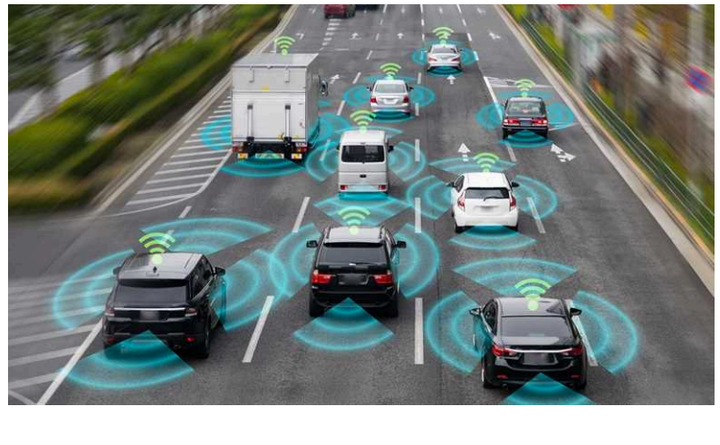
- **Big, Big, Big Data**

Trend 2:
Interconnectivity at Scale



Worldwide Sensor Network

Smart City



Connected Vehicles

Interconnection,
Interoperation
Integration & Scaling
Challenges

Low End

High End

Ubiquitous embedded devices

- **Large-scale networked embedded systems**
- **Seamless integration with a physical environment**

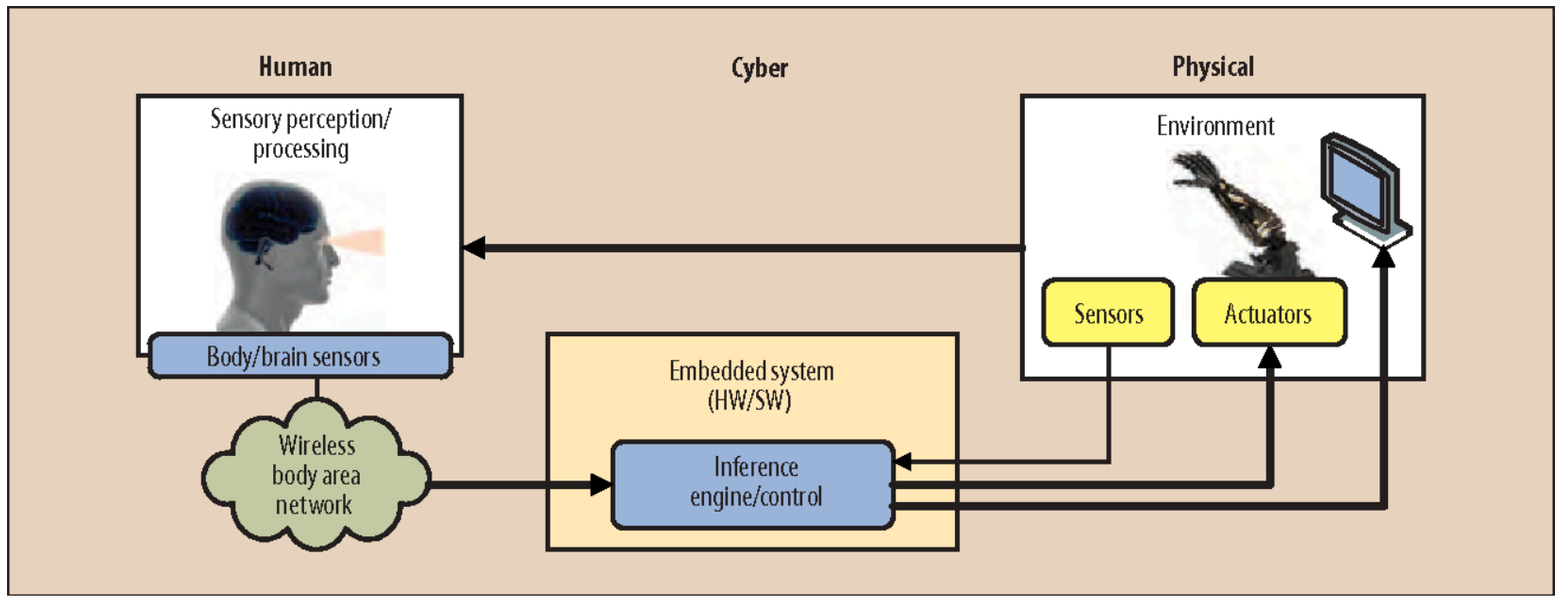
Complex systems with global integration

- **Global Information Grid**
- **Smart Building Environment**

Trend 3: Closing the Loop/ Autonomy

Closing the Loop

- X in the Loop
  - A system that requires X’s interaction
- Human in the loop
  - A model that requires human interaction



Schirner, Gunar et al. “Human-inthe-Loop Cyber-Physical Systems.” .

Closing the Loop

Kozloduy Nuclear Power Plant - Control Room of Unit

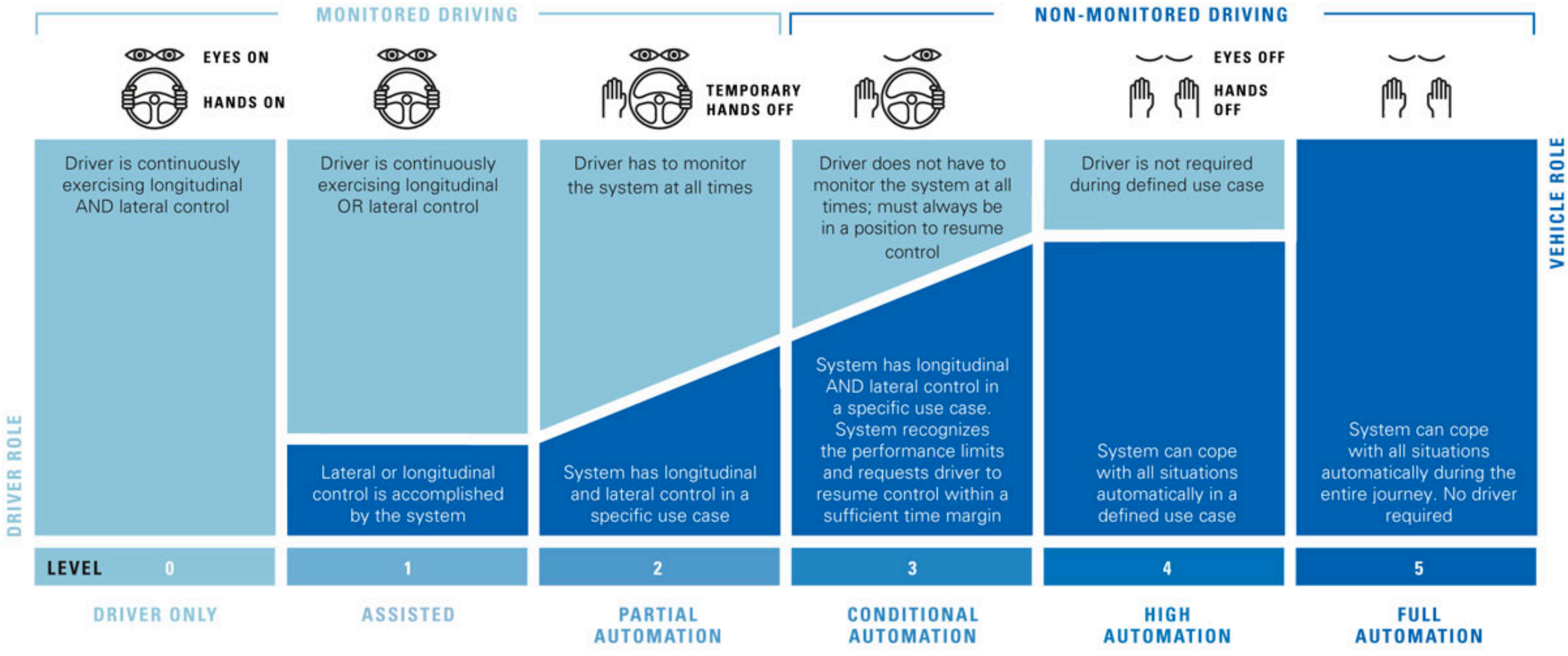
Why Autonomy?

“Human-in-the-loop” too slow!

The exponential proliferation of embedded devices (afforded by Moore’s Law) is ***not*** matched by a corresponding increase in human ability to consume information!

Increasing autonomy, direct world access. Move human out of the loop

Autonomous Driving



Mike Lemanski

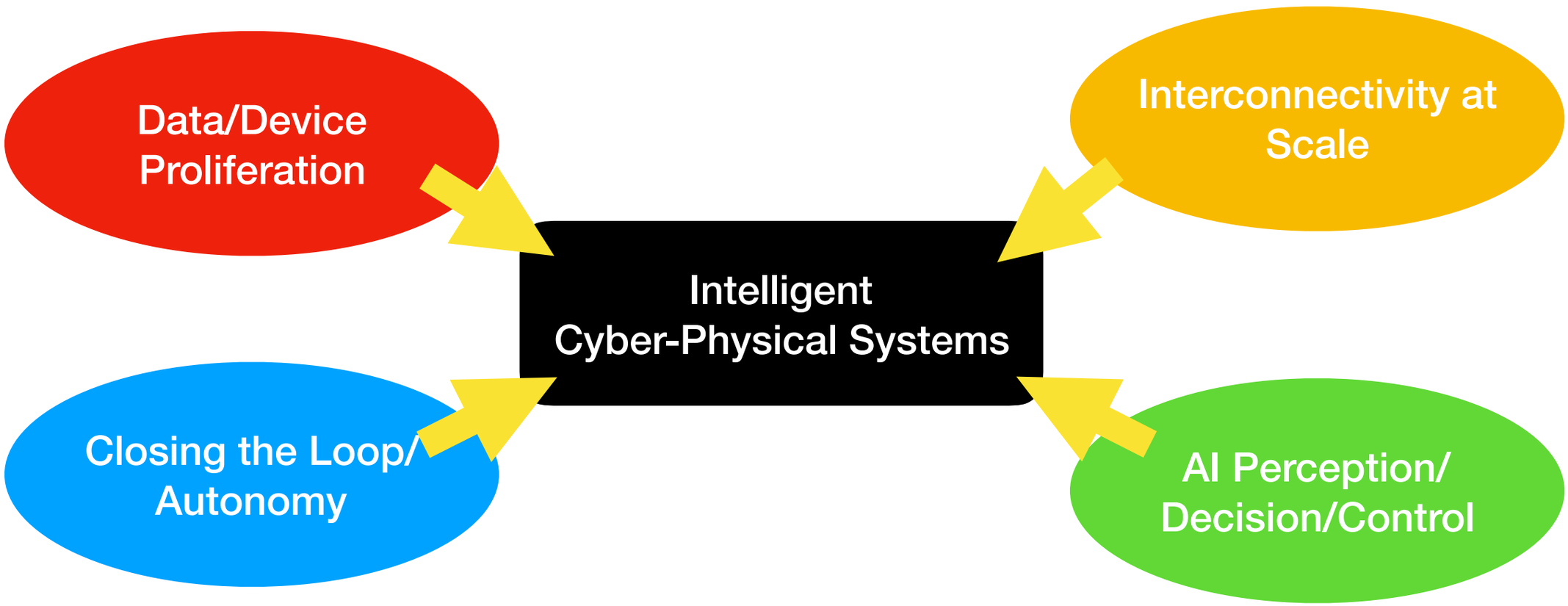
Trend 4: AI Perception/ Decision/Control

Autonomous Driving

War with Drone

As computers play a bigger role in warfare, the dangers to humans rise - Economist, “Artificial intelligence and war” Sep 5th 2019

Confluence of Trends



- Overarching Challenges:
  - Interaction Complexity and Scalability
  - Composition and Compositionality
  - Uncertainty/ Untrustworthy Control

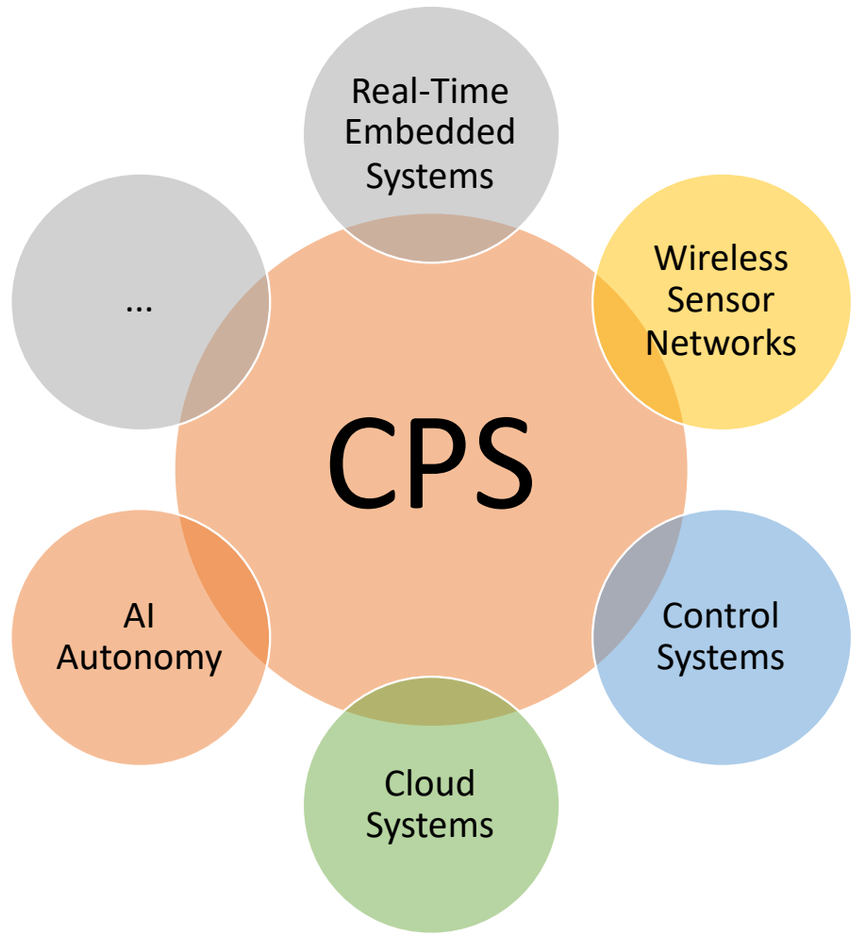
What is CPS?

- Physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core.

- Tight conjoining of and coordination between computational and physical resources.

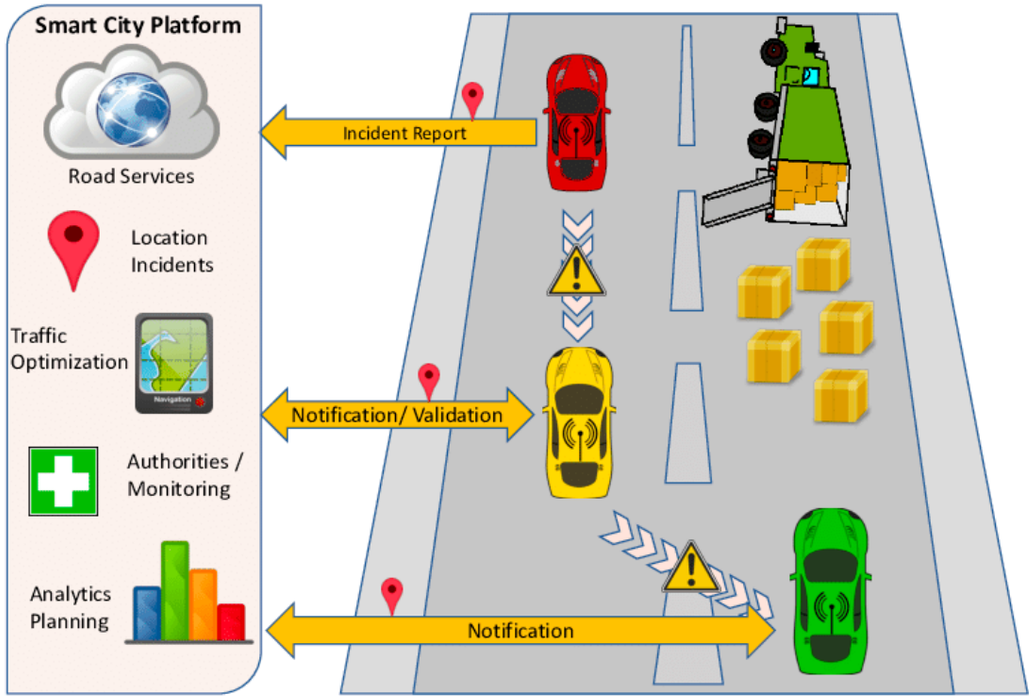
- Exceeds today's systems in adaptability, autonomy, efficiency, functionality, reliability, safety, and usability

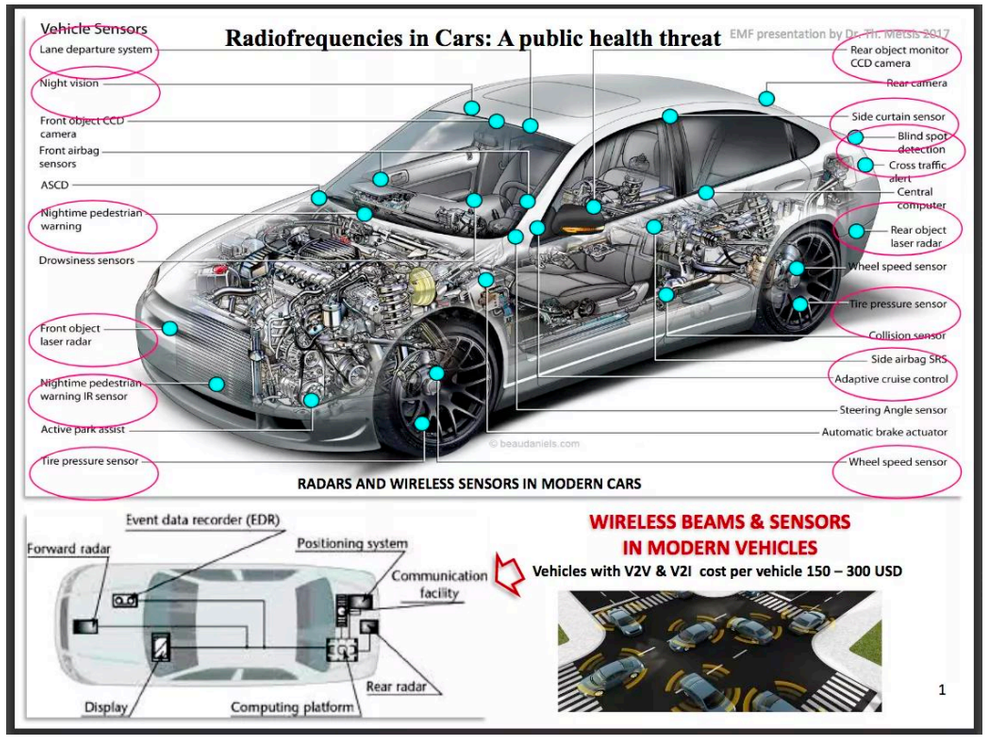
- Convergence of computation, communication, information, and control



Automotive

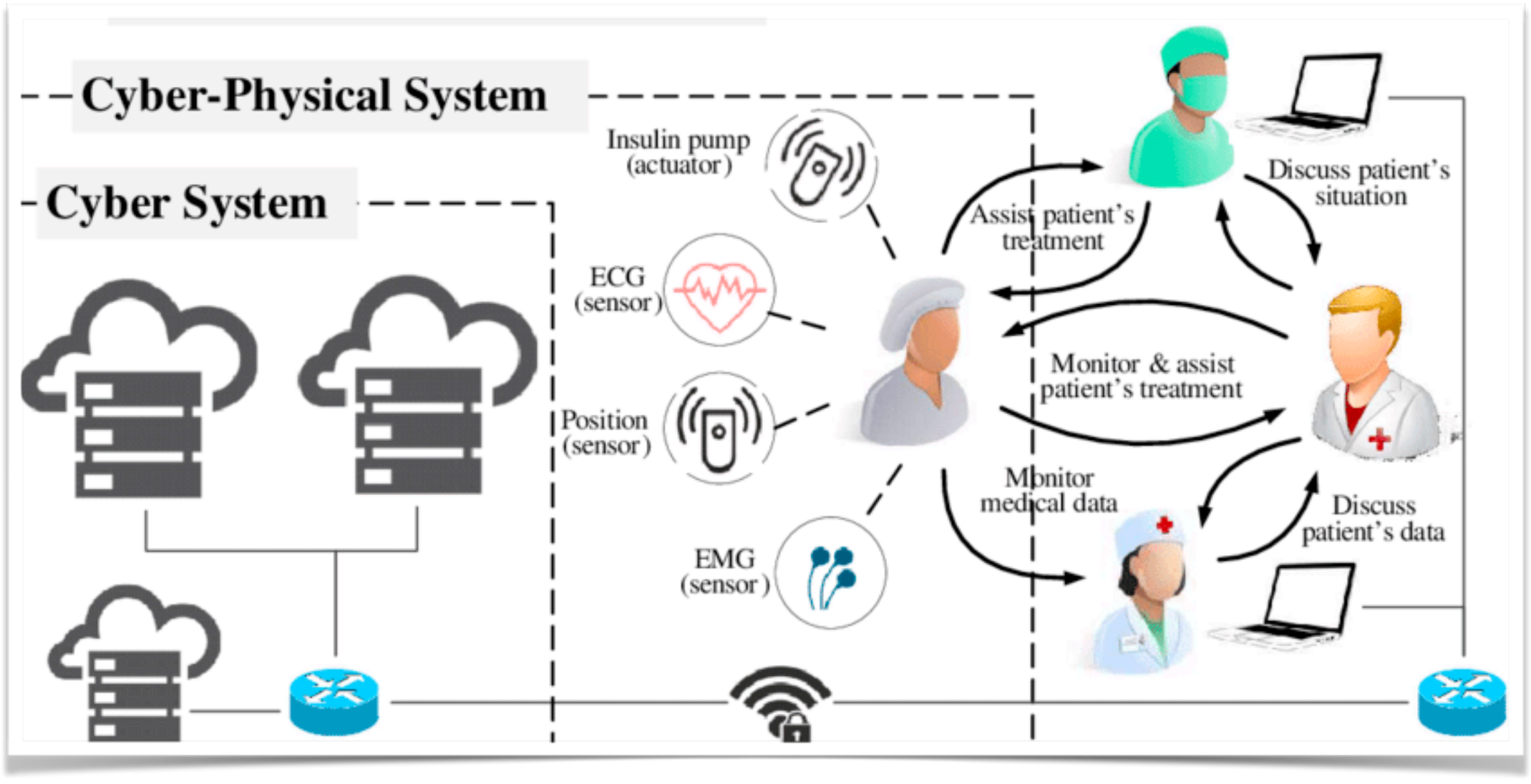
- 30-90 processors per car
  - Engine control, break system, airbag deployment system
  - Windshield wiper, door locks, entertainment systems





- Cars are sensors and actuators in V2X networks
  - Active networked safety alerts
  - Autonomous (self-)driving cars

Medical CPS


Cyber-Physical System
Cyber System
Insulin pump
(actuator)
ECG
(sensor)
Position
(sensor)
EMG
(sensor)
Assist patient's
treatment
Discuss patient's
situation
Monitor & assist
patient's treatment
Monitor
medical data
Discuss
patient's data

Heath Care CPS

- Operating Room of the Future
  - Closed loop monitoring and control; multiple treatment stations, plug and play devices; robotic microsurgery
  - System coordination challenge

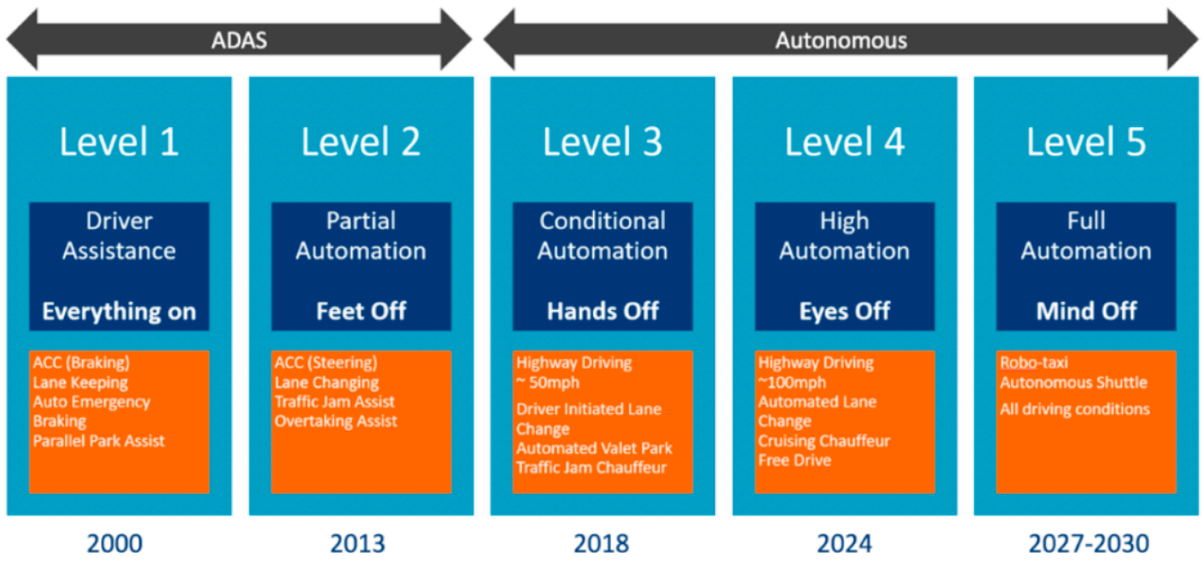
- Progress in bioinformatics:
  - Systems biology; disease dynamics, control mechanisms
  - Personalized medicine

Self-Driving Car

- https://www.digitaltrends.com/cars/the-future-of-self-driving-cars/

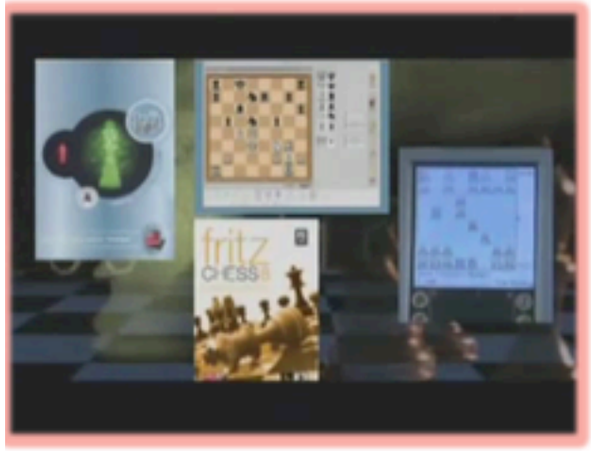
- https://www.youtube.com/watch?v=aNkKZuKbVKc

- More convenient and even safer



Thinking Machine

Deep Blue



1997

딥 블루는 가능한 모든 경우를 조사하여 다음 수를 결정

Watson

2011

2011년 기능 시험으로서 왓슨은 퀴즈 쇼 제퍼디!에 참가하였으며, 이는 이제까지도 유일한 인간 대 컴퓨터 대결

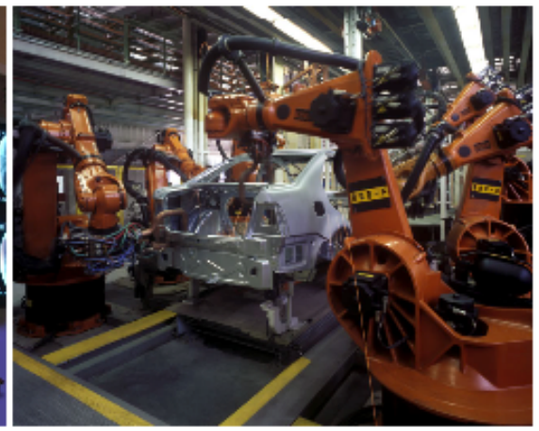
AlphaGo

2016

구글(Google)의 딥마인드(DeepMind Technologies Limited)가 개발한 인공지능(AI, Artificial Intelligence) 바둑 프로그램

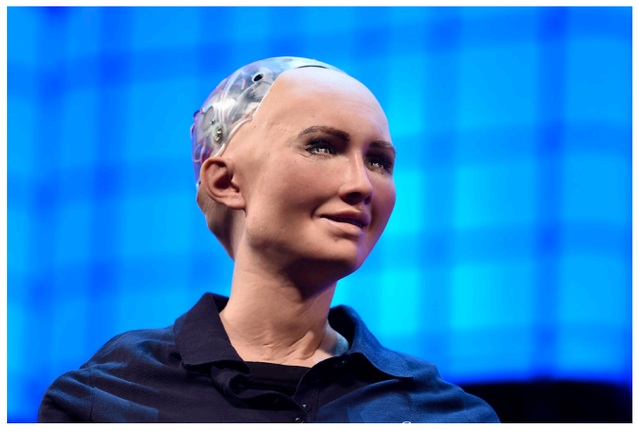
Robotics

Robotic Surgery



Factory Automation

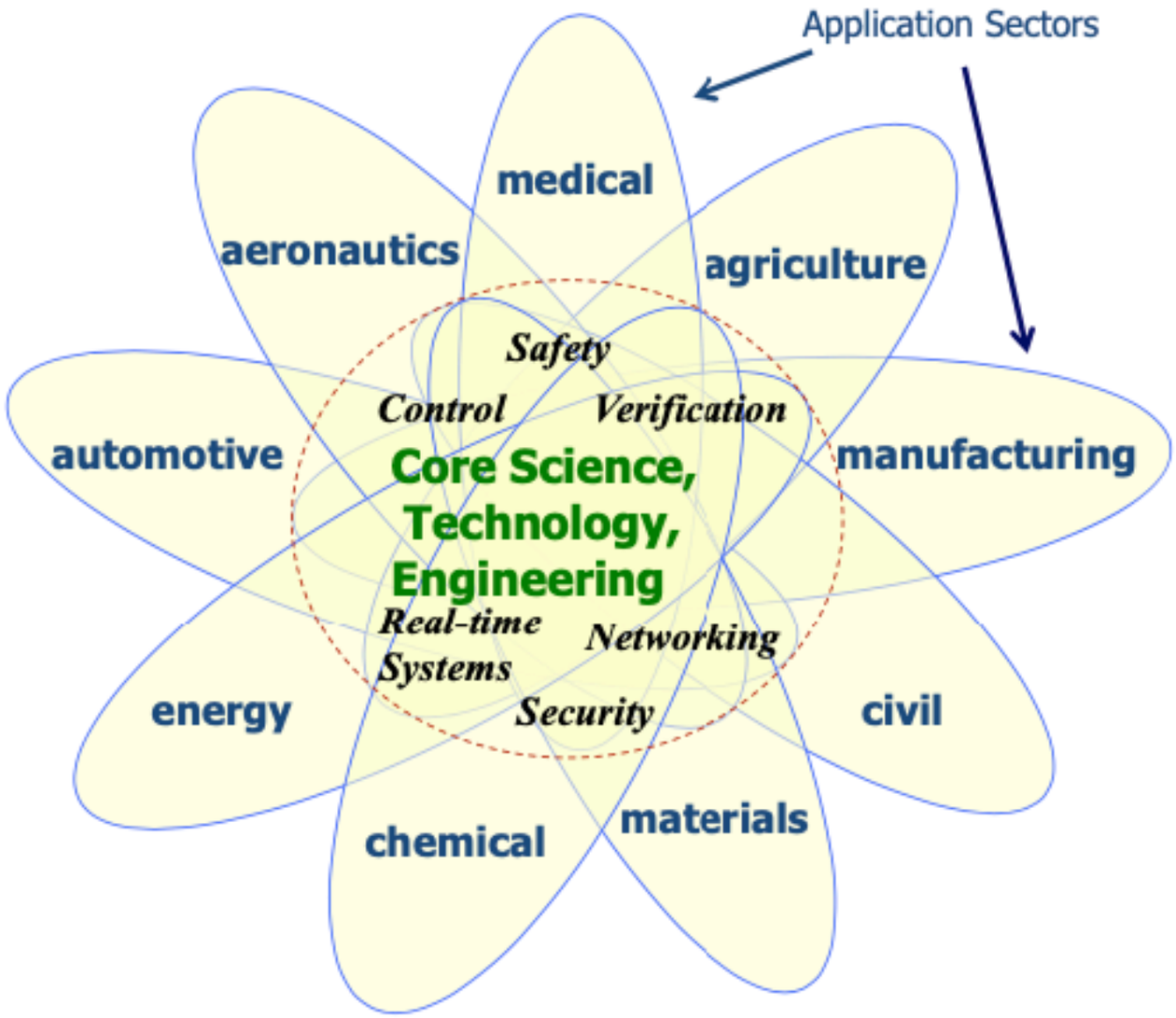
Military Robot Vehicles



Humanoid

- Manufacturing and Logistics Robotics
- Medical and Healthcare Robotics Service Robotics
- Humanoid (https://www.youtube.com/watch?v=3IFuv1AVouM)

Application Domain of CPS



CPS Grand Challenges

- **Zero automotive traffic fatalities**, injuries minimized, and significantly reduced traffic congestion and delays
- **Blackout-free electricity** generation and distribution
- **Energy-aware buildings**
- **Smart life assistants** for busy, older or disabled people
- **Location-independent access** to world-class medicine
- **Physical critical infrastructure** that calls for preventive maintenance
- **Reduce testing and integration time** and costs of complex CPS systems (e.g. avionics) by one to two orders of magnitude
- **Self-correcting, self-certifying, self-healing** CPS for “one-off” applications
- **Human-like thinking machine** free from erroneous behaviors

Where do we start from?

- Take a look at yourself and think where you are.

- Proactive and Passive? Or PROPassive?

In Next Class

- Real-Time System,
- Requirement Engineering: Use case
- …

Heath Care CPS

- National Health Information Network, Electronic Patient Record initiative
    - Medical records at any point of service
    - Hospital, OR, ICU, ..., EMT?
- Home care: monitoring and control
    - Pulse oximeters (oxygen saturation), blood glucose monitors, insulin infusion pumps, accelerometers (falling, immobility), wearable networks (gait analysis), ...