Secure Autonomous and Cyber-Physical Systems

CS 599 001/ECE 599 004

Winter 2022

Prof. Sibin Mohan

https://bit.ly/secureauto2022

Definitions

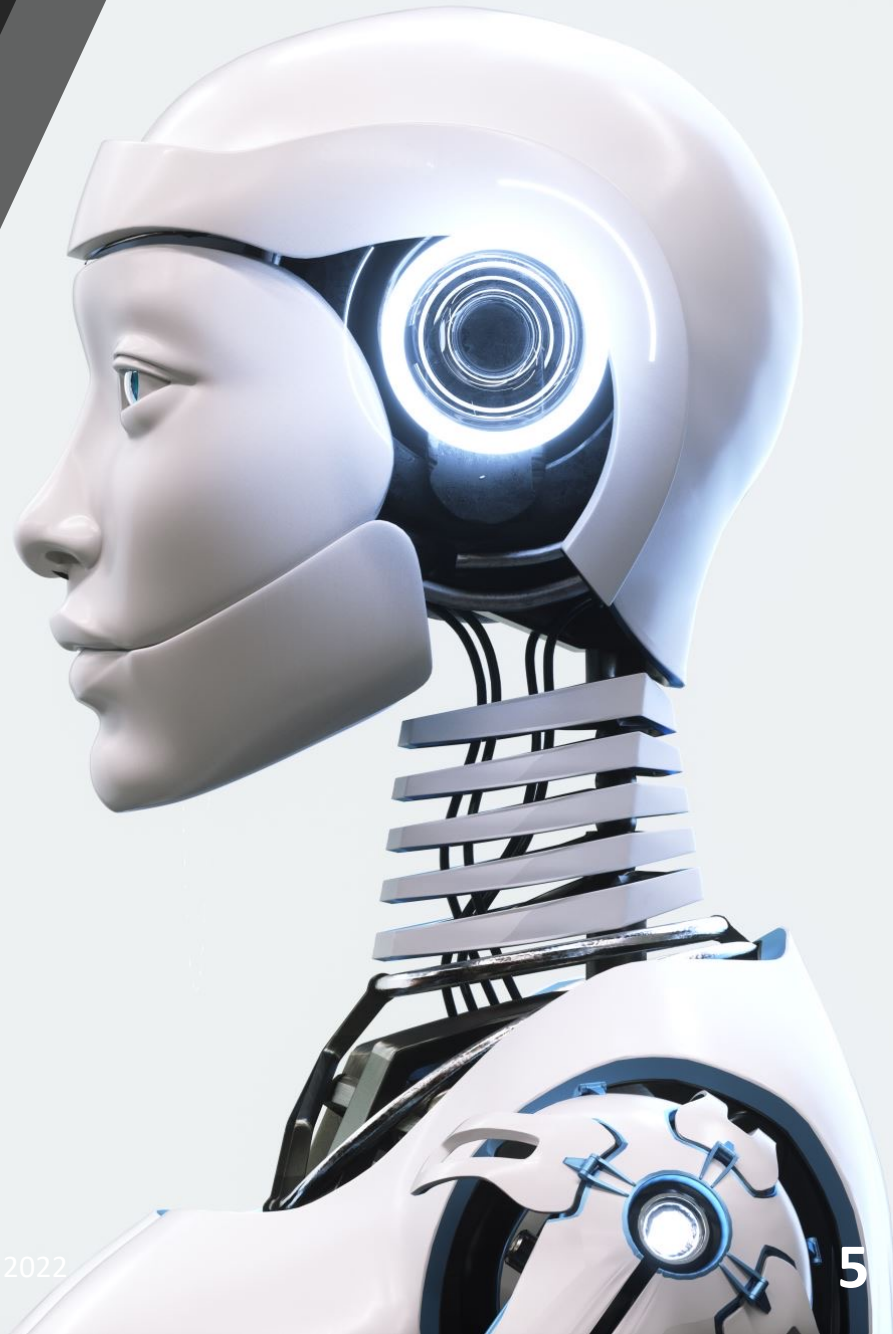
- Autonomy
- Cyber-Physical Systems
- Real-Time Systems

Autonomy

Aspects of Autonomy?

Autonomy | A Definition

Autonomy is the **ability to perform given tasks** based on the **system's perception without human intervention**



Detour | This Course

Secure Autonomous and Cyber-Physical Systems (CPS)
CS 599 001/ECE 599 004
Instructor: **Prof. Sibin Mohan** [Sibin/Prof. Sibin/Prof. Mohan]
Days/Times: MON/WED **2 PM – 3:50 PM**
Location: **BAT 150**
Contact: **Canvas**
Office Hours: **MON/WED 4:00 – 5:00 PM** [**KEC 3049**]

Course Content

- *design* of autonomous, cyber-physical and real-time systems
- *sensing*, IMU, GPS, Radar, LIDAR, Camera, etc.
- *localization*, Simultaneous localization And Mapping (SLAM)
- Extended Kalman Filter (EKF)
- *attacks* and *defenses* related to all of these topics
- *privacy and ethical issues* in the design and deployment of autonomous systems

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Security

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Course Content | MPs

- Hands-on exercises [3]
- open-source simulation and control platforms
  - Gazebo
  - VEINS
- Final MP will have a leaderboard-style competition!

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Course Content | Paper Reading+Presentation

- Exploring state-of-the-art research in the area
- Learn how to **read** and **critique** relevant papers
- Present papers in class
  - Each student presents **two papers** over the course of the term

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Grading Critera

In-class participation	**5%**
MP1 [V2X/VEINS]	**20%**
MP2 [UAV Security/Gazebo]	**20%**
MP3 [V2X Attack/Leaderboard/VEINS]	**25%**
Paper Reading/Critique	**30%**

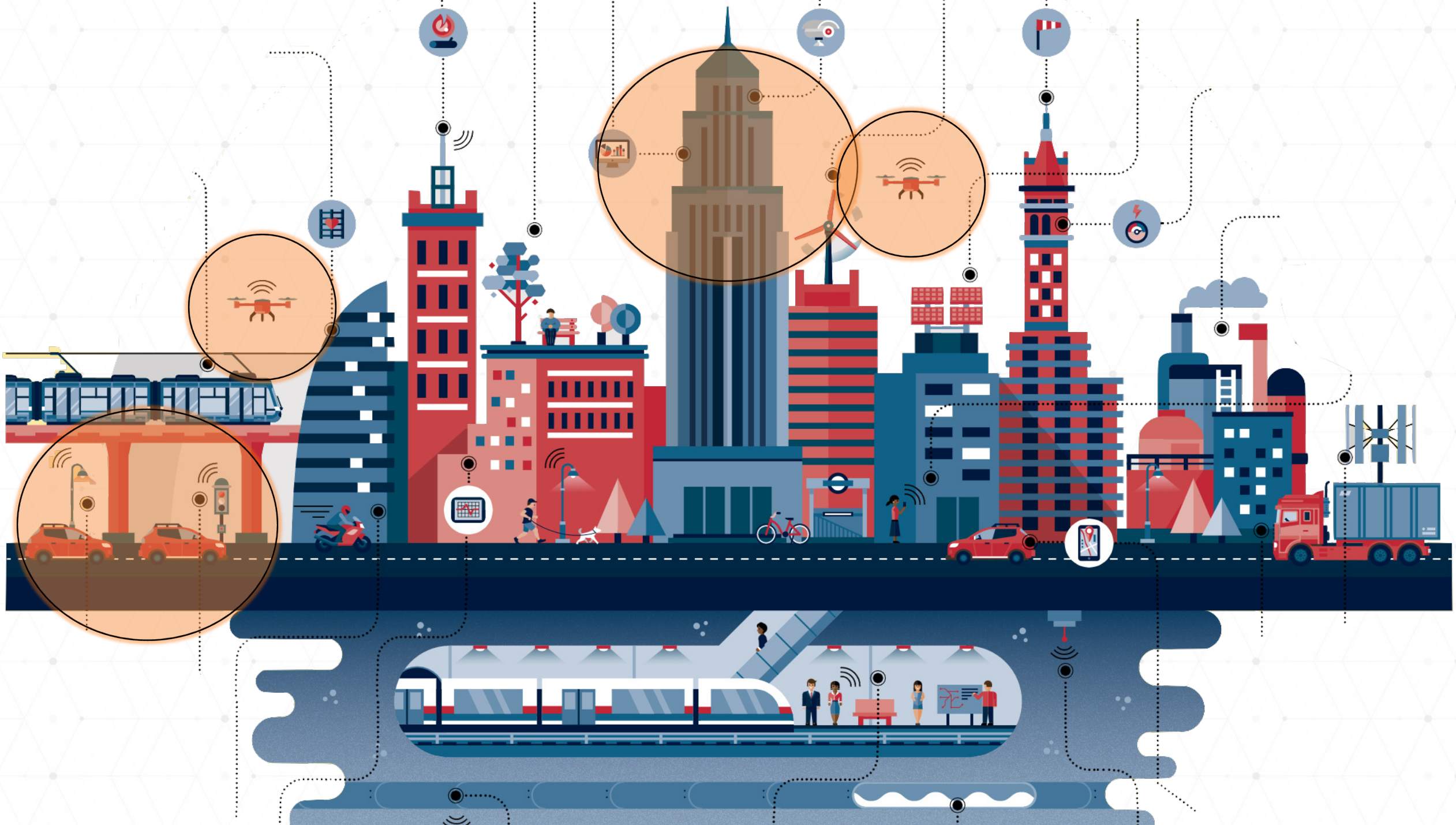
Grades

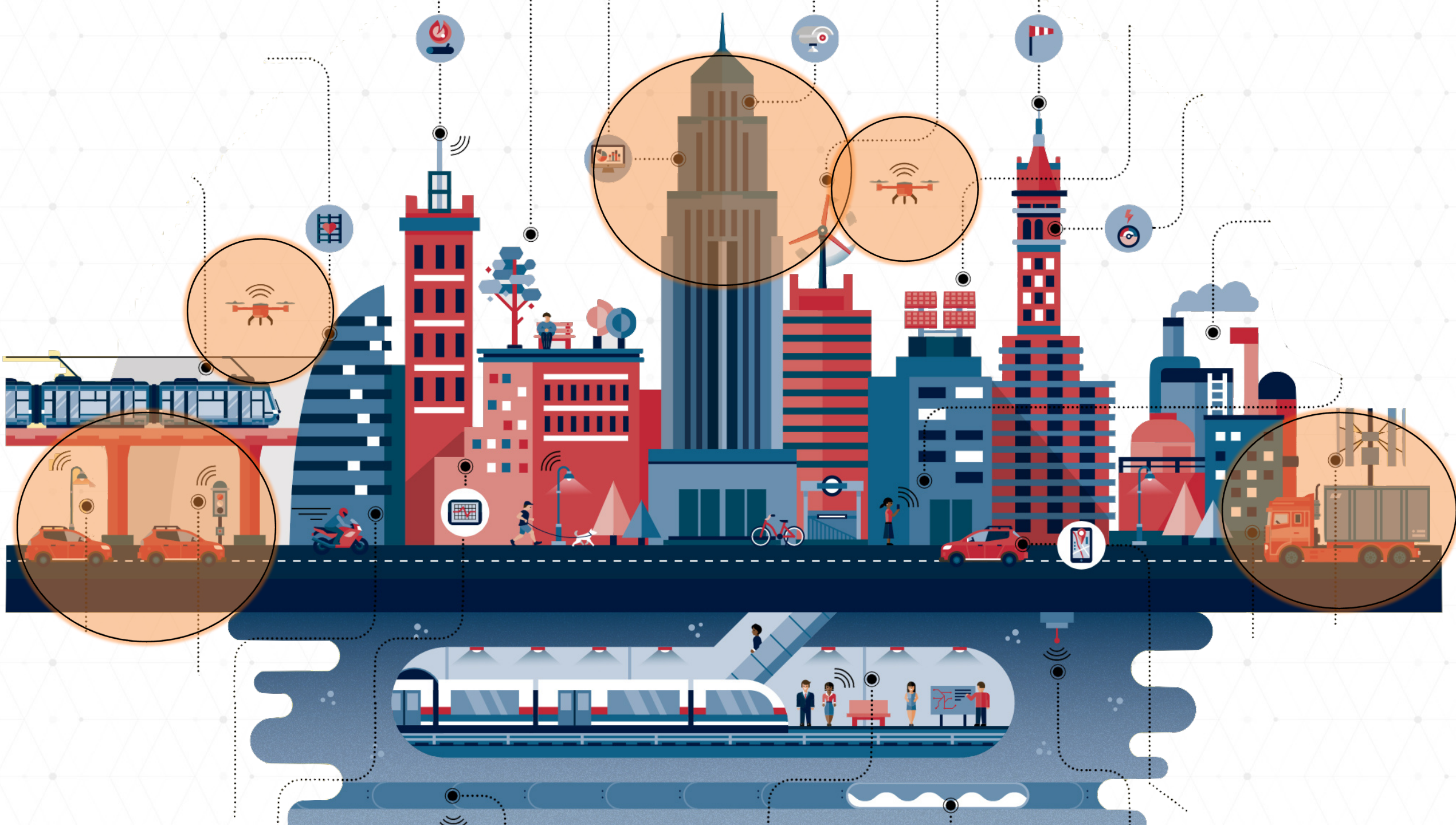
Conversion from numerical to letter grades

95 - 100 = A
90 - 94 = A-
87 – 89 = B+
83 - 86 = B
80 - 82 = B-
77 - 79 = C+
73 - 76 = C
70 - 72 = C-
67 - 69 = D+
63 - 66 = D
60 - 62 = D-
< 60. = F

End of Detour

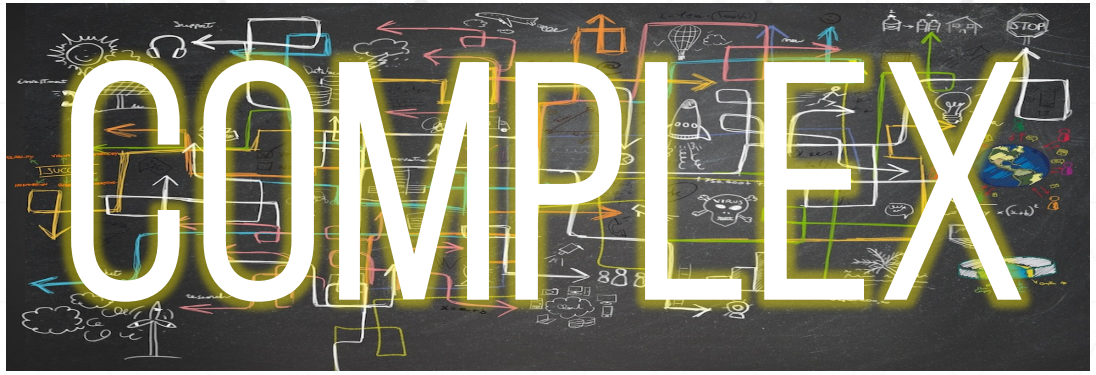
- Back to definitions/concepts
  - Cyber-Physical Systems
  - Real-Time Systems
  - Security/Safety/Resiliency





LARGE

LARGE



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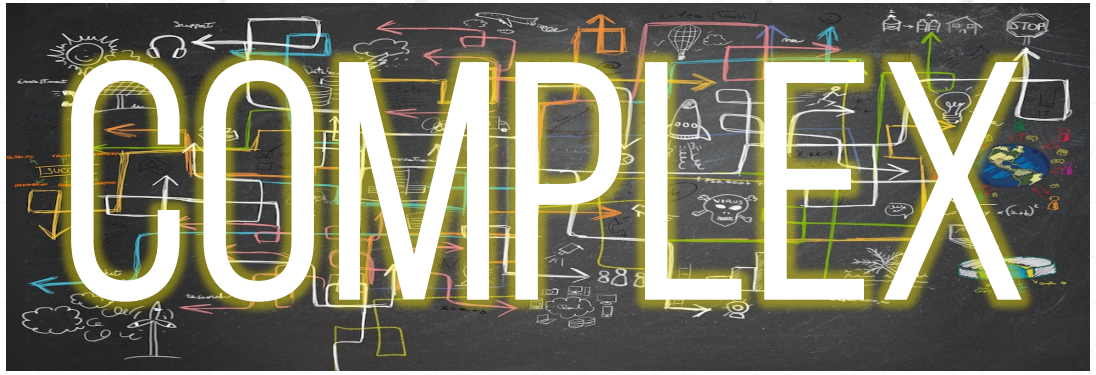

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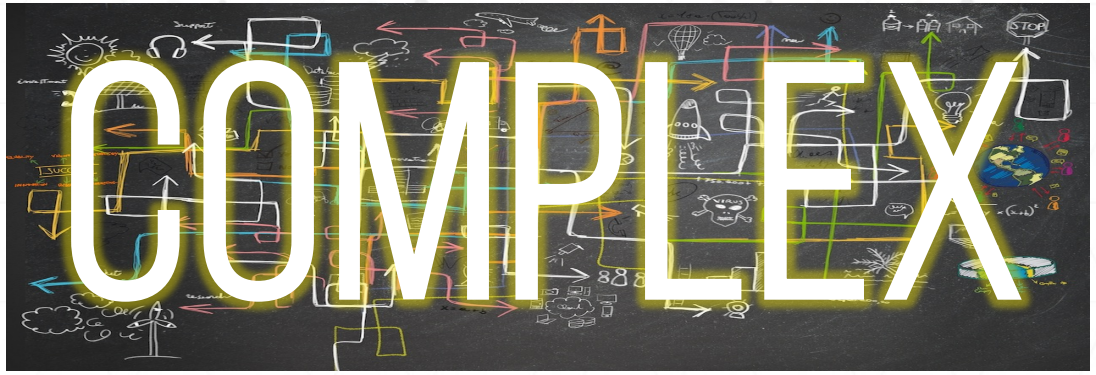


SYSTEMS

LARGE

COMPLEX

MODELING, ANALYSIS, SECURITY ARE **HARD PROBLEMS**

INTERCONNECTED

SYSTEMS

CYBER-PHYSICAL SYSTEMS

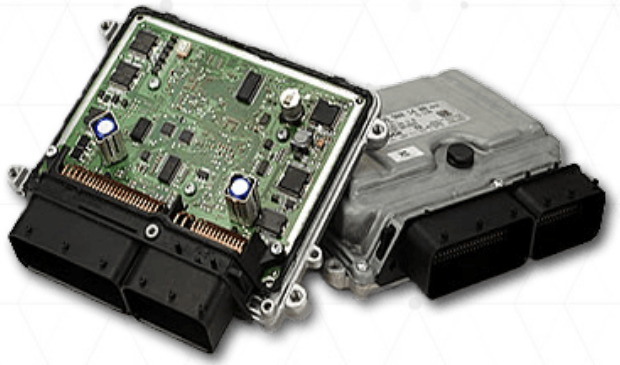
CYBER-PHYSICAL SYSTEMS

CYBER

```
                TS      TEMPRG0         # FOR GENERALIZED RETURN TO OTHER BANKS.
P40A/P          TC      BANKCALL        # SUBROUTINE TO CHECK PGNCS CONTROL
                CADR    G+N,AUTO# AND AUTO STABILIZATION MODES
                CCS     A               # +0 INDICATES IN PGNCS, IN AUTO
                TCF     TURNITON        # + INDICATES NOT IN PGNCS AND/OR AUTO
                CAF     APSFLBIT        # ARE WE ON THE DESCENT STAGE?
                MASK    FLGWRD10
                CCS     A
                TCF     GOBACK          # RETURN
                CAF     BIT5            # YES, CHECK FOR AUTO-THROTTLE MODE
                EXTEND
                RAND    CHAN30
                EXTEND
                BZF     GOBACK          # IN AUTO-THROTTLE MODE -- RETURN
TURNITON        CAF     P40A/PMD        # DISPLAYS V50N25 R1=203 PLEASE PERFORM
                TC      BANKCALL        # CHECKLIST 203 TURN ON PGNCS ETC.
                CADR    GOPERF1
                TCF     GOTOP00H        # V34E TERMINATE
                TCF     P40A/P          # RECYCLE
GOBACK          CA      TEMPRG0
```

software, control algorithms, code

networking, communication



ECUs, microcontrollers, PLCs

CYBER-PHYSICAL SYSTEMS

CYBER

PHYSICAL

```
                TS      TEMPR60         # FOR GENERALIZED RETURN TO OTHER BANKS.
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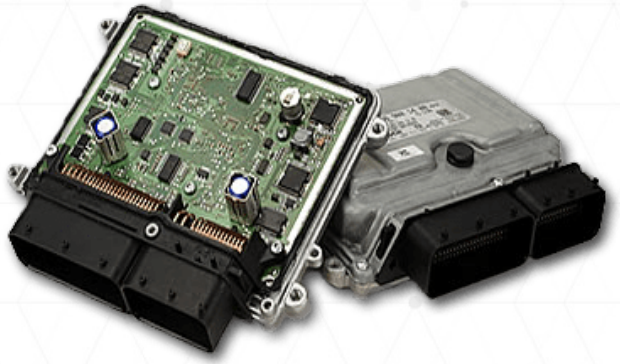

ECUs, microcontrollers, PLCs

sensors

actuators, motors

”plants”

CYBER-PHYSICAL SYSTEMS

CYBER

software, control algorithms, code

networking, communication

ECUs, microcontrollers, PLCs

PHYSICAL

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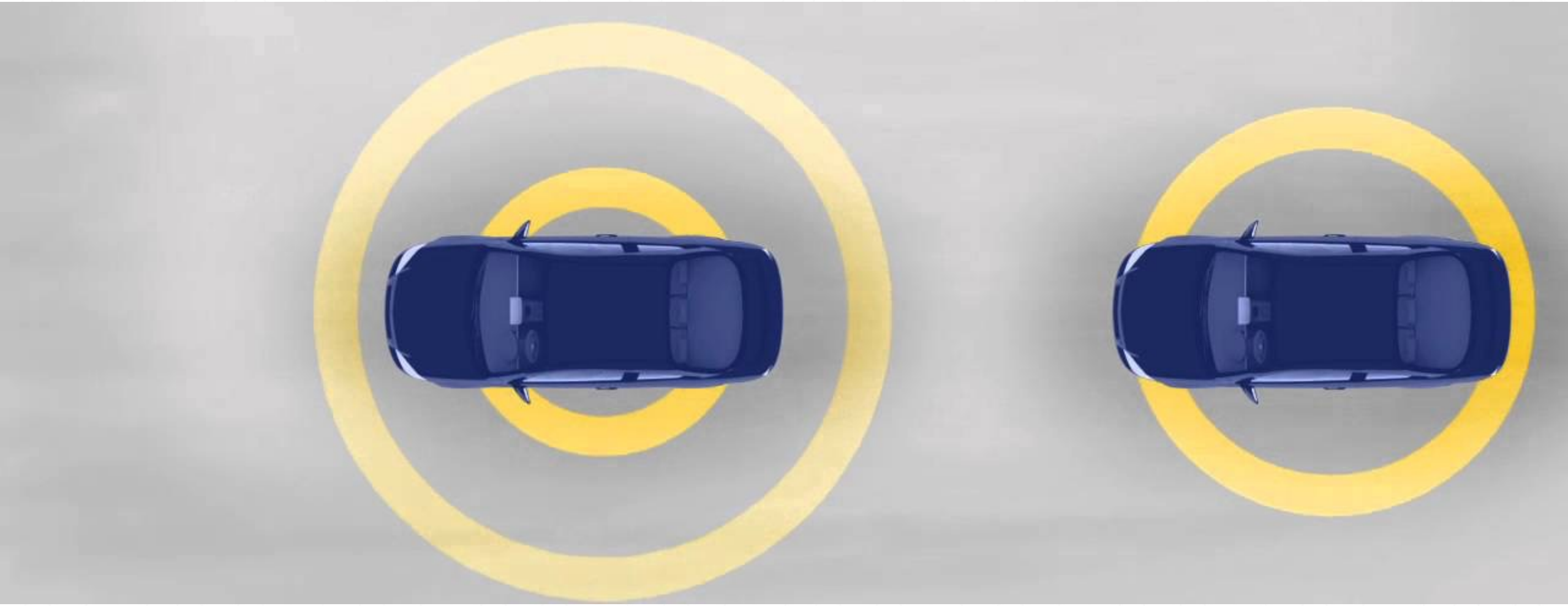
SENSING AND ACTUATION IS EVERYWHERE

SENSING/ACTUATION IN THE REAL WORLD



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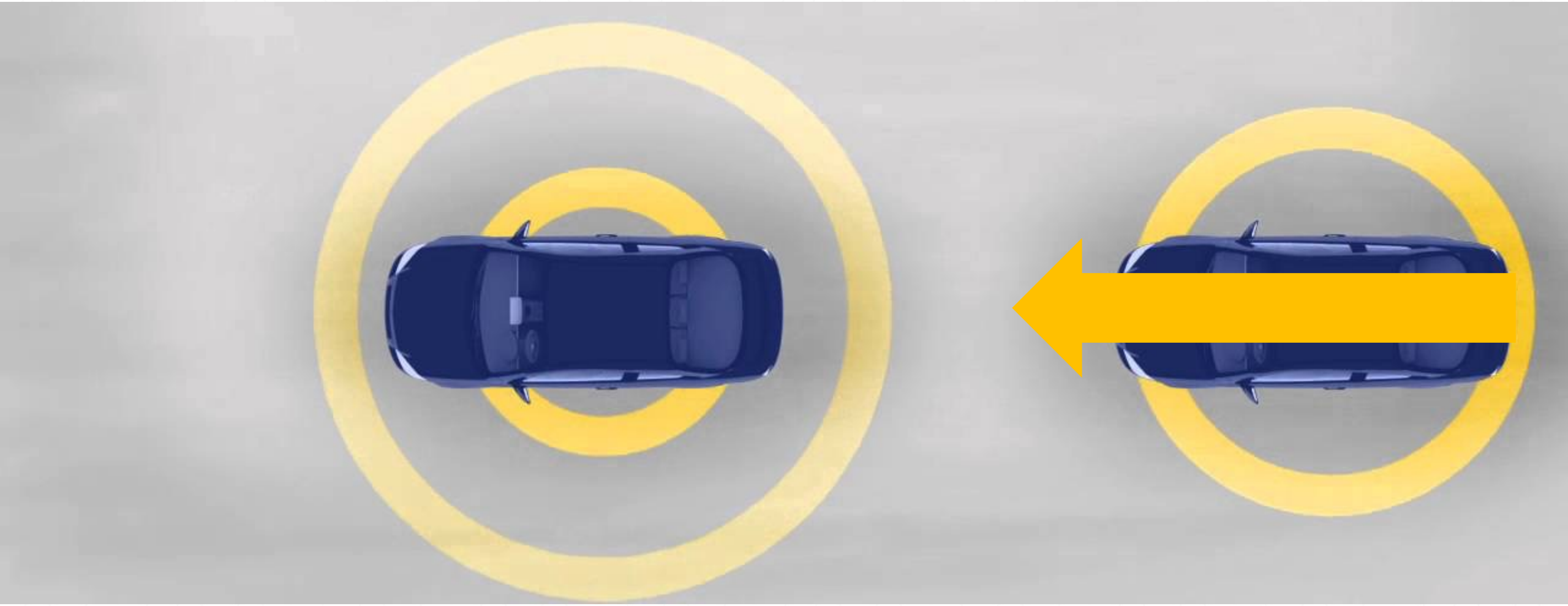
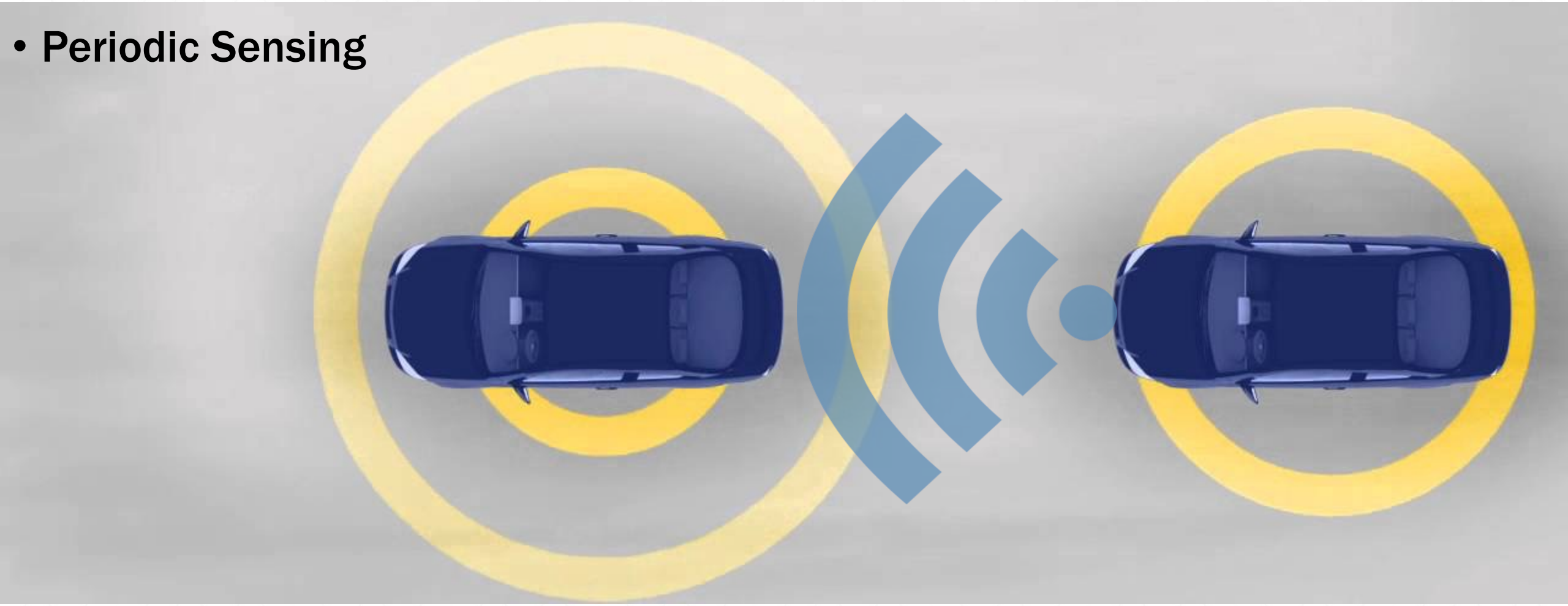


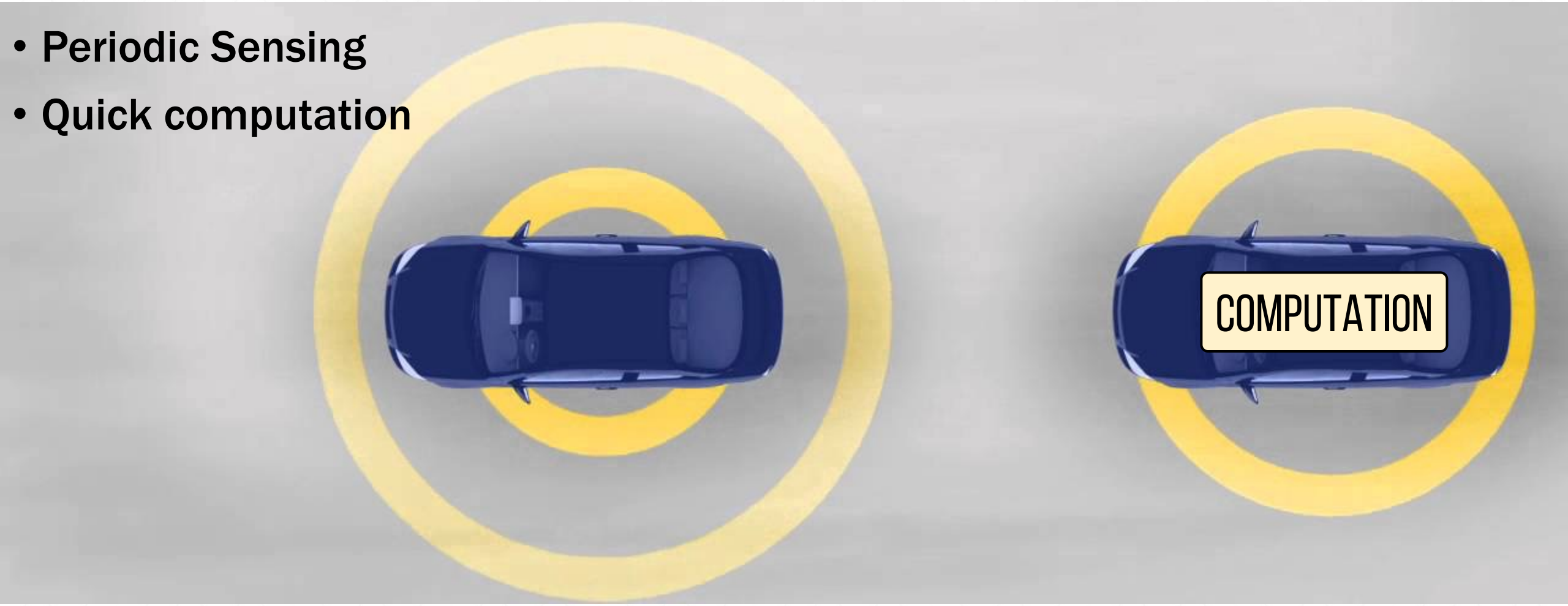
SENSING/ACTUATION IN THE REAL WORLD

- Periodic Sensing



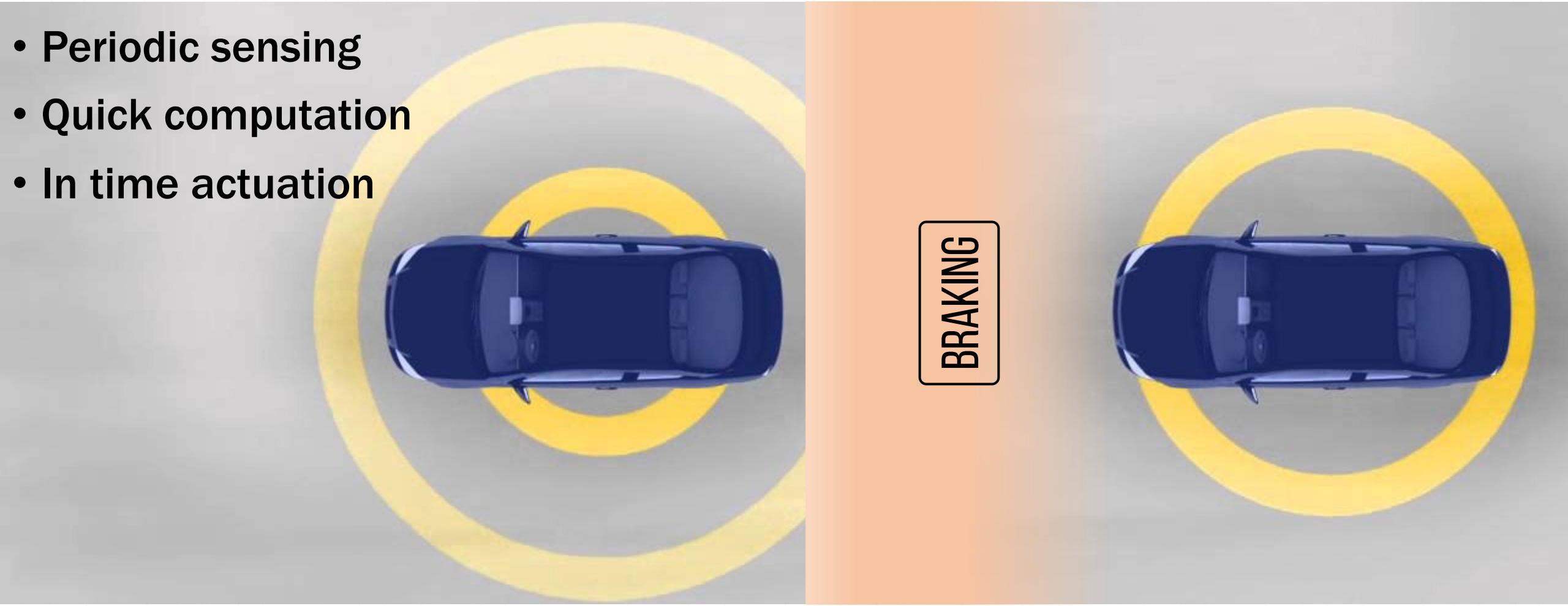
SENSING/ACTUATION IN THE REAL WORLD

- Periodic Sensing
- Quick computation



SENSING/ACTUATION IN THE REAL WORLD

- Periodic sensing
- Quick computation
- In time actuation



PERIODIC SENSING

QUICK COMPUTATION

IN TIME ACTUATION


PERIODIC SENSING
QUICK COMPUTATION
IN TIME ACTUATION
TIME

REAL-TIME SYSTEMS

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"A system that requires both, **logical** as well as **temporal** correctness."

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- **Temporal correctness defined as a constraint: deadline**

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  - **Deadline passes → usefulness drops**

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ONE OF THE **FOUNDATIONAL** AREAS FOR CYBER-PHYSICAL SYSTEMS

REAL-TIME SYSTEMS

Consider an airbag deployment system

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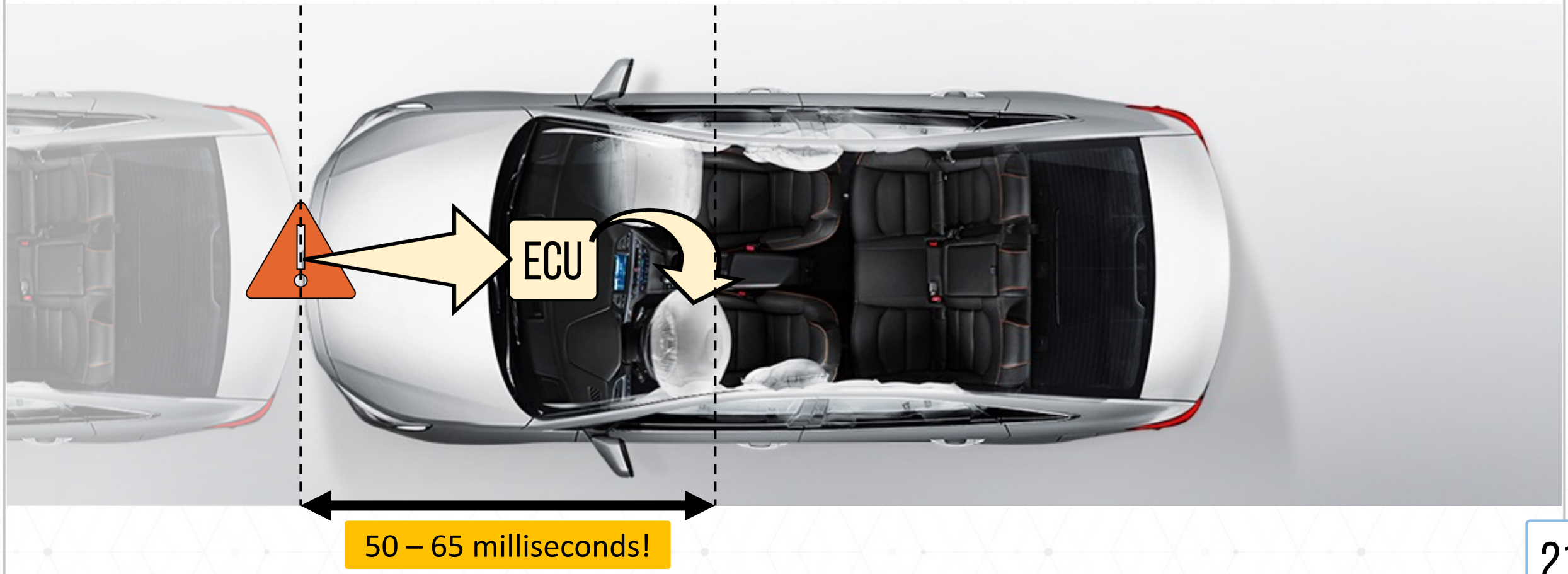

REAL-TIME SYSTEMS

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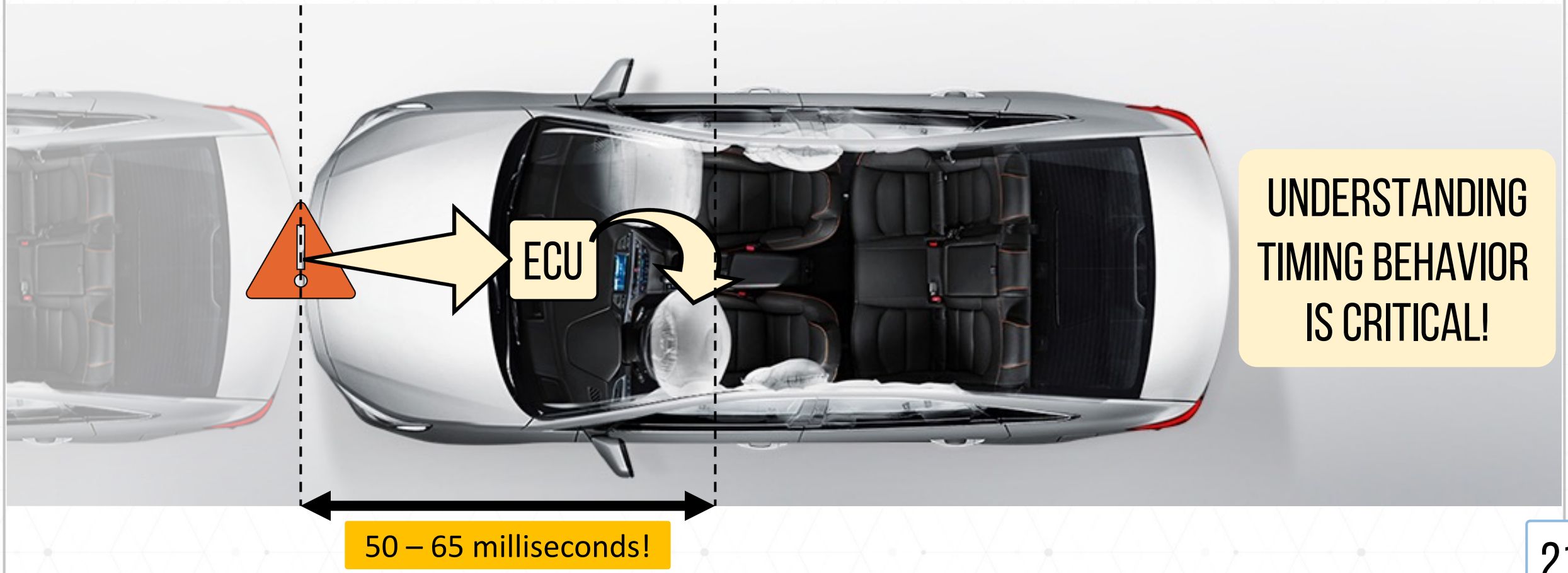

UNDERSTANDING TIMING BEHAVIOR IS CRITICAL!

REAL-TIME SYSTEMS

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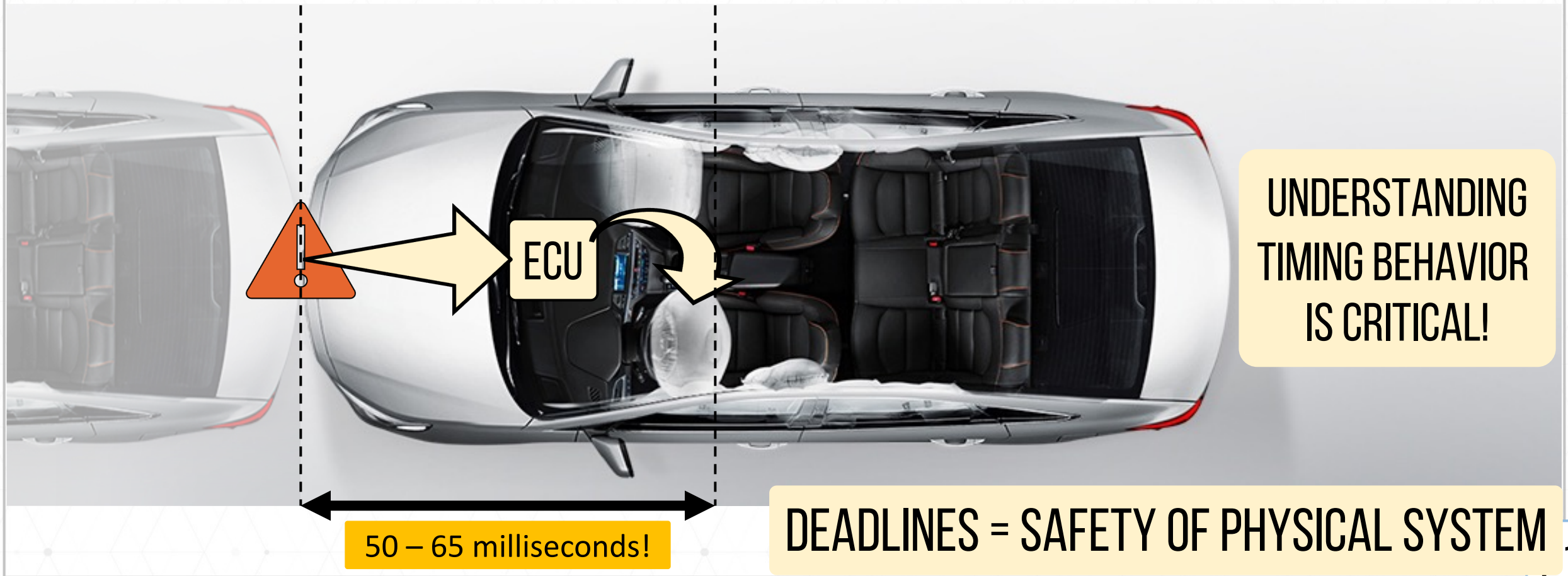

UNDERSTANDING TIMING BEHAVIOR IS CRITICAL!

DEADLINES = SAFETY OF PHYSICAL SYSTEM

REAL-TIME SYSTEMS

Consider an airbag deployment system

WHY NOT RUN CODE REALLY FAST?

50 – 65 milliseconds!

UNDERSTANDING TIMING BEHAVIOR IS CRITICAL!

CPS Challenges

Limited Resources
- Computational power, energy, cost

Timing Requirement
- Safety, reliability, deadlines

CPS Challenges

Limited Resources
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Timing Requirement
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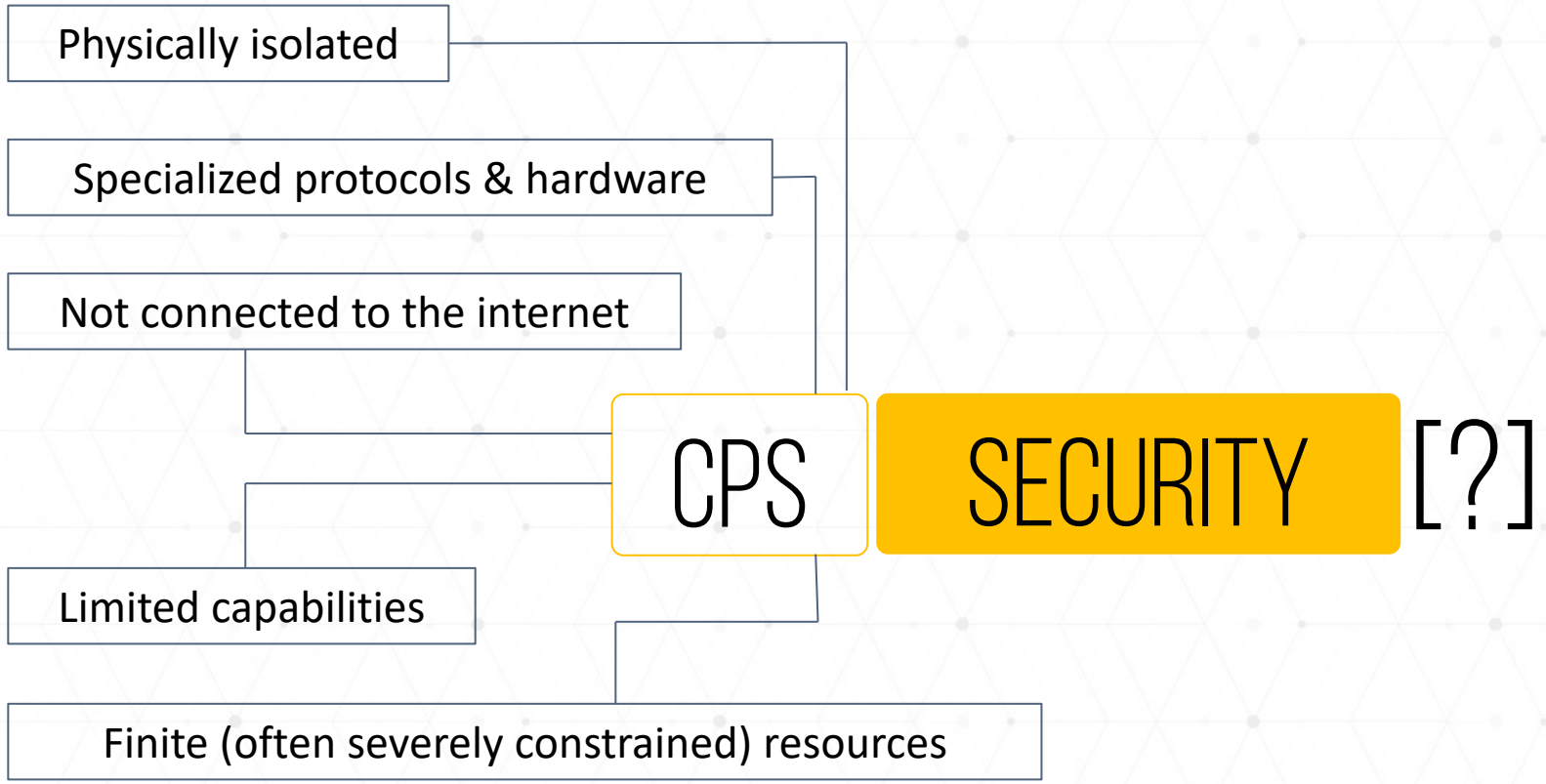
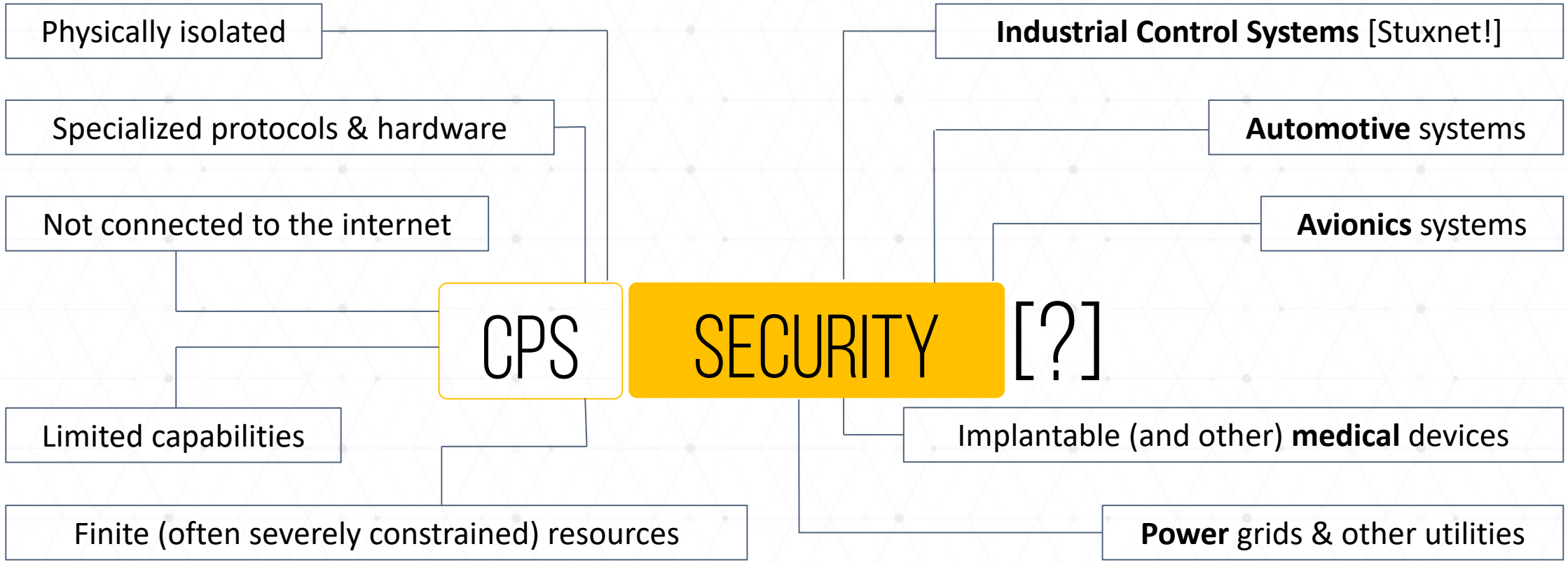
Security/System Upgradability
- Schedulability, Verifiability

CPS SECURITY


Physically isolated
Specialized protocols & hardware
Not connected to the internet
CPS
SECURITY
[?]
Limited capabilities
Finite (often severely constrained) resources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[?]
Industrial Control Systems [Stuxnet!]
Automotive systems
Avionics systems
Implantable (and other) medical devices
Power grids & other utilities

Autonomous Cars | UAVs | Medical/surgical robots | IoT

Delivery robots | Smart Manufacturing Systems

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CPS SECURITY RESILIENCY

RESILIENCY?

RESILIENCY?

SOFTWARE ERRORS CAN RESULT IN PHYSICAL FAILURES

RESILIENCY?

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SECURITY AND RESILIENCY

SECURITY AND RESILIENCY

ATTACKER INTENT

SECURITY AND RESILIENCY

ATTACKER INTENT ..... Cause systems to crash

SECURITY AND RESILIENCY

ATTACKER INTENT ..... Cause systems to crash

NOT CONCERNED WITH DATA BEING STOLEN

SECURITY AND RESILIENCY

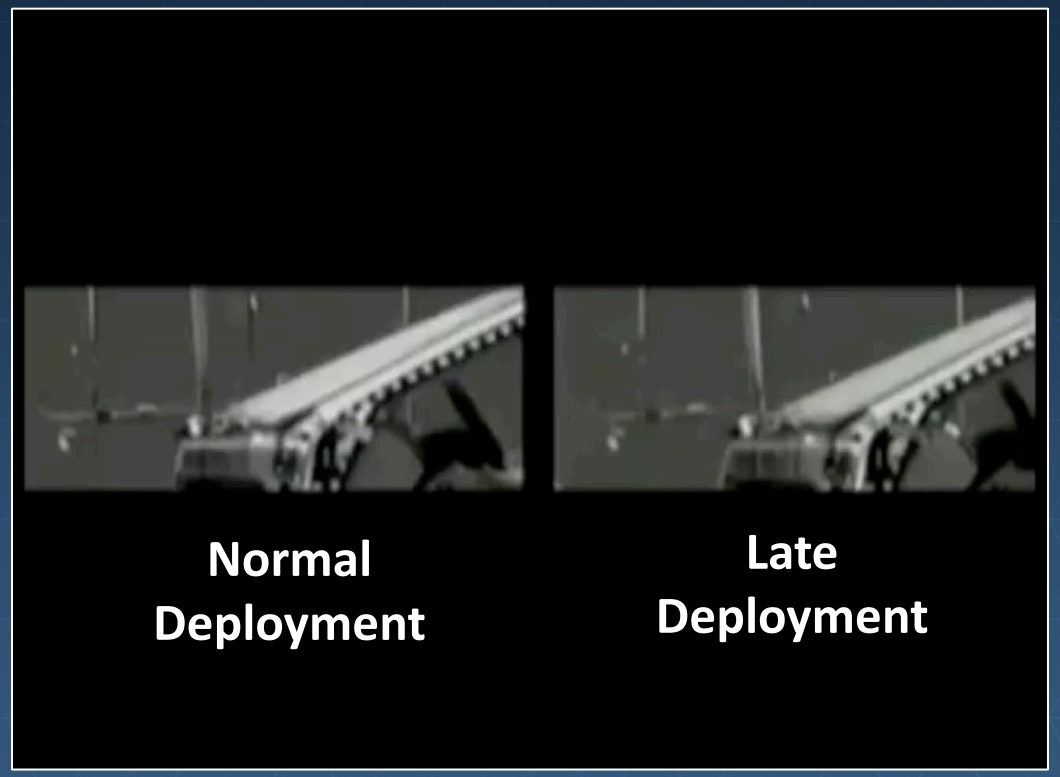
ATTACKER INTENT

Cause systems to crash

What if airbag deployment is delayed?

SECURITY AND RESILIENCY

ATTACKER INTENT ..... Cause systems to crash



Next Lecture

- **Design** of Autonomous Systems
- **Sensing**
  - IMU, GPS, Radar, LIDAR, Camera, etc.