Cyber-Physical Systems

Laura Nenzi

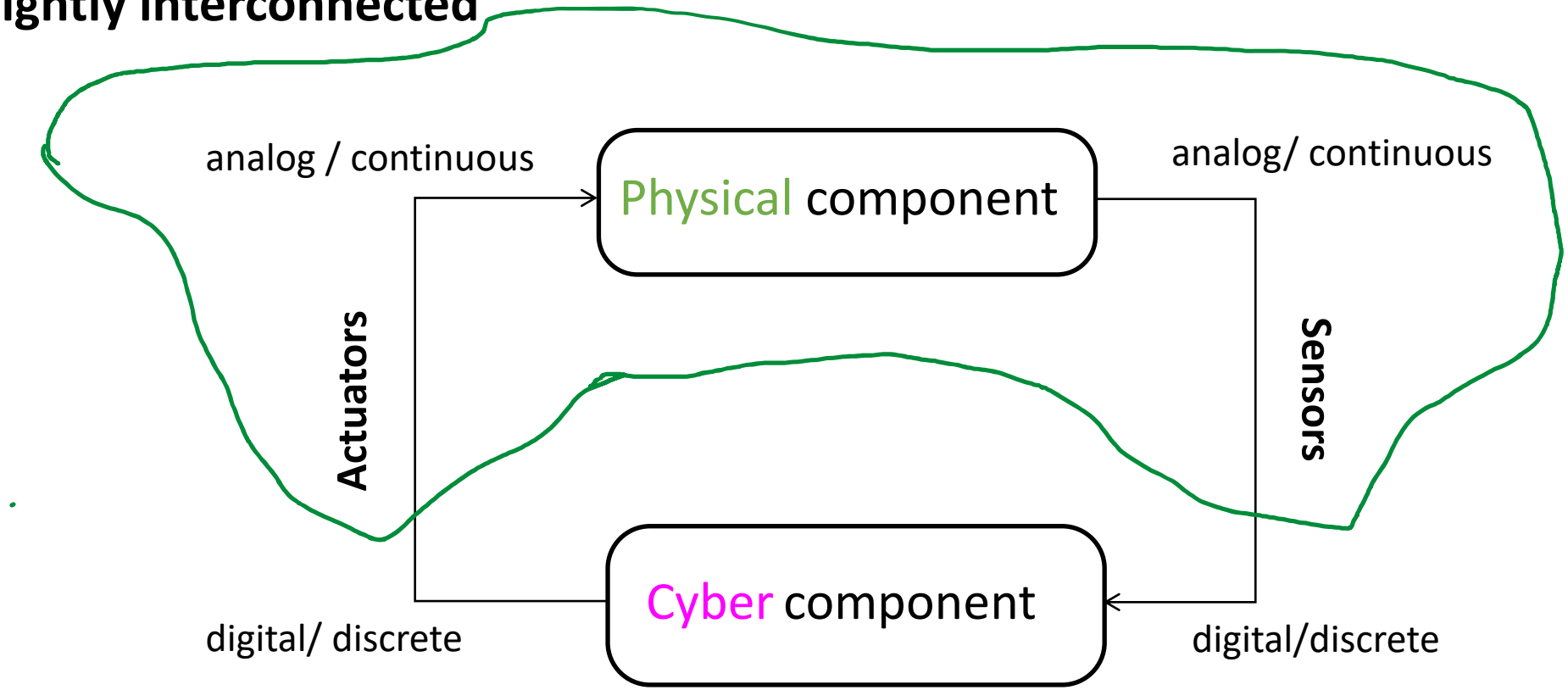
Università degli Studi di Trieste
II Semestre 2019

Lecture 2: Modeling (Introduction)

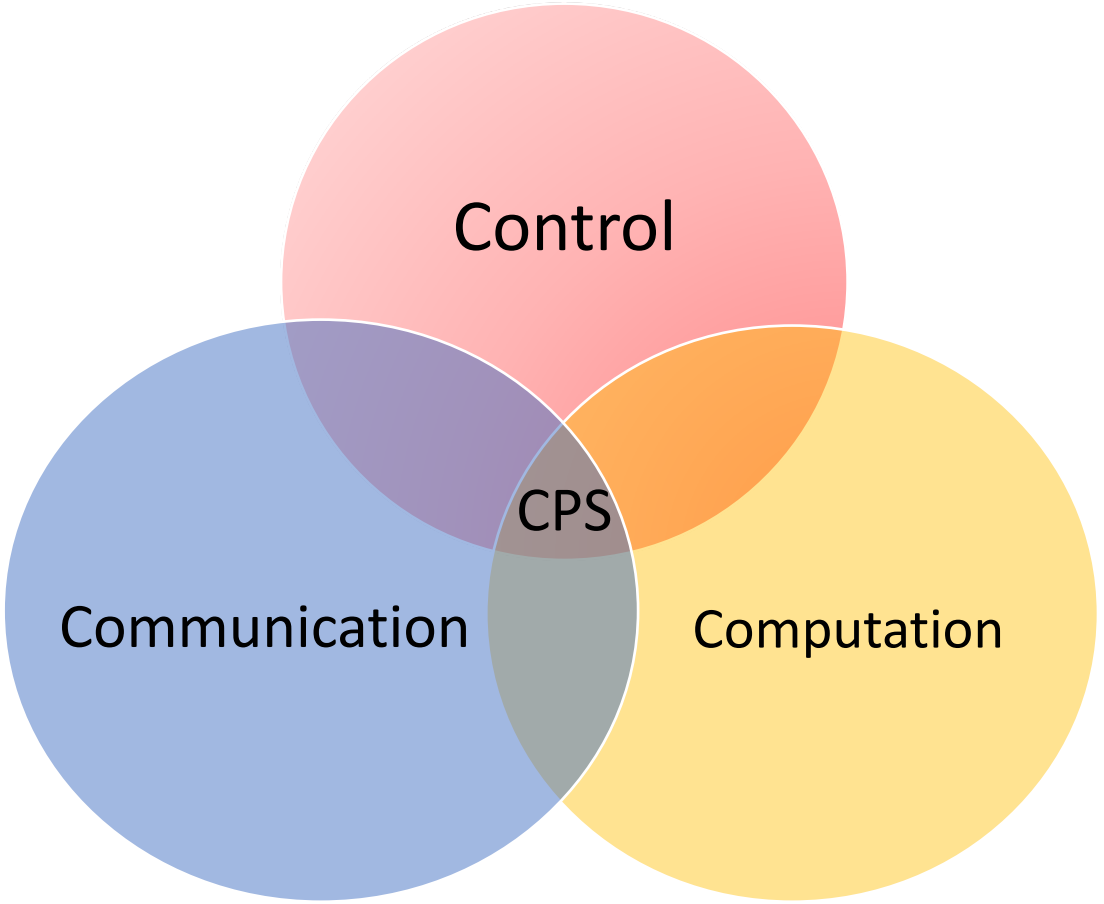
[Many Slides due to J. Deshmukh, Toyota]

Cyber-Physical System (CPS)

Combination of physics (environment / plant / process / system) with a cyber (computation / software / code) components **potentially networked** and **tightly interconnected**



Cyber-Physical System (CPS)

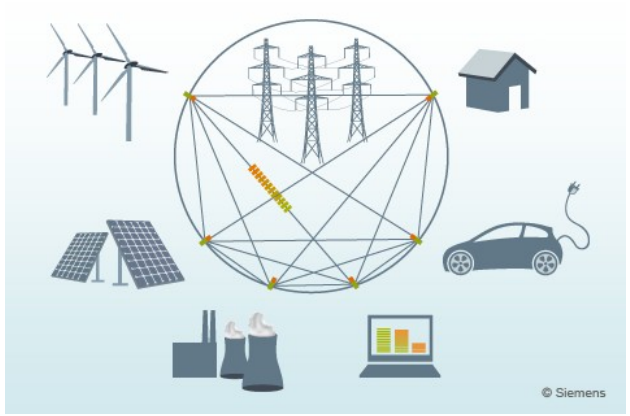


Cyber-Physical System (CPS)

- **Embedded Systems**: are computational system embedded in a physical system. Big difference is that in CPS environment is the physical component

- **Hybrid Systems**: are a mathematical abstraction, CPS are real-world objects.

Cyber-Physical System (CPS)



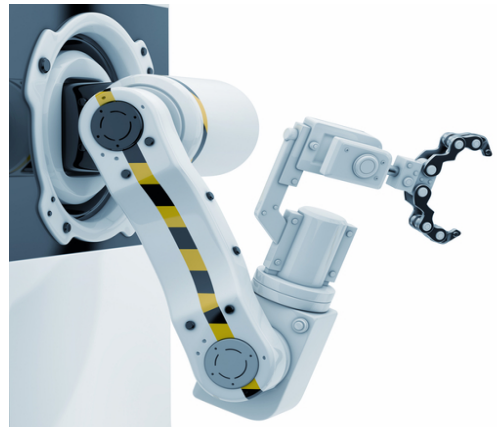
Medical Devices

Power Networks

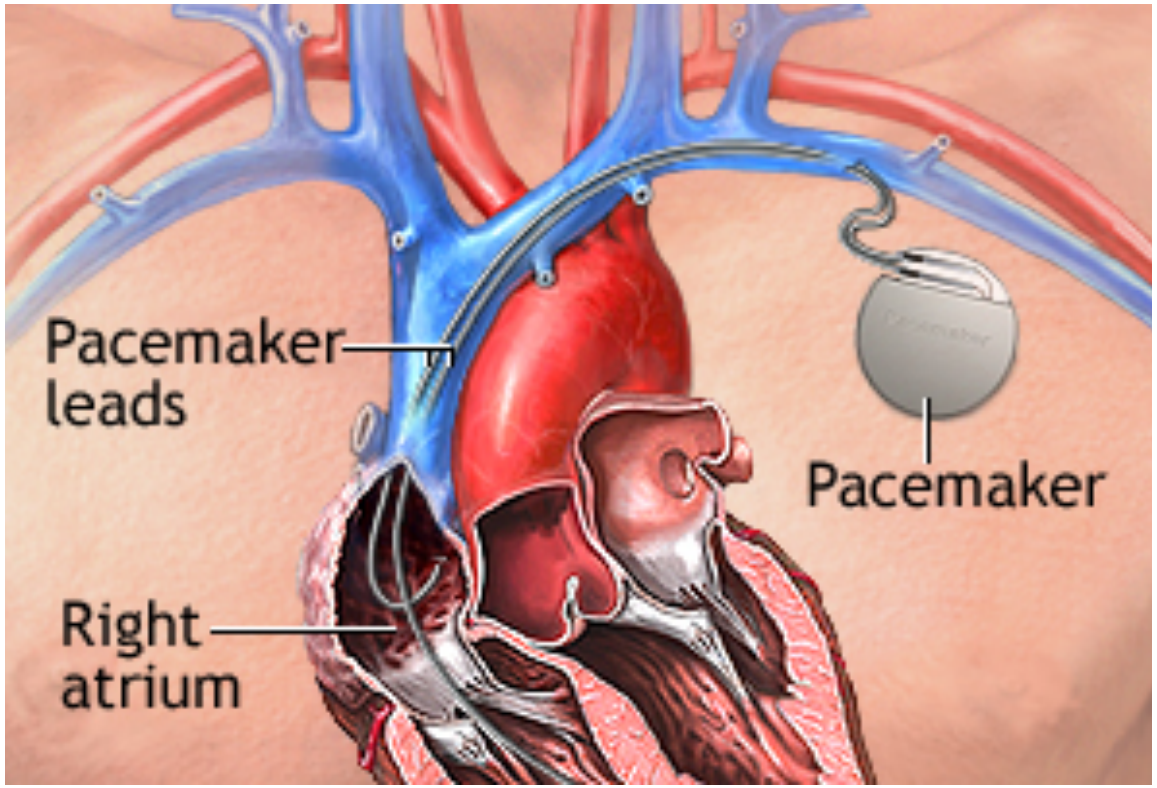
CPS

Robotic Systems

Vehicular Systems



Medical Device

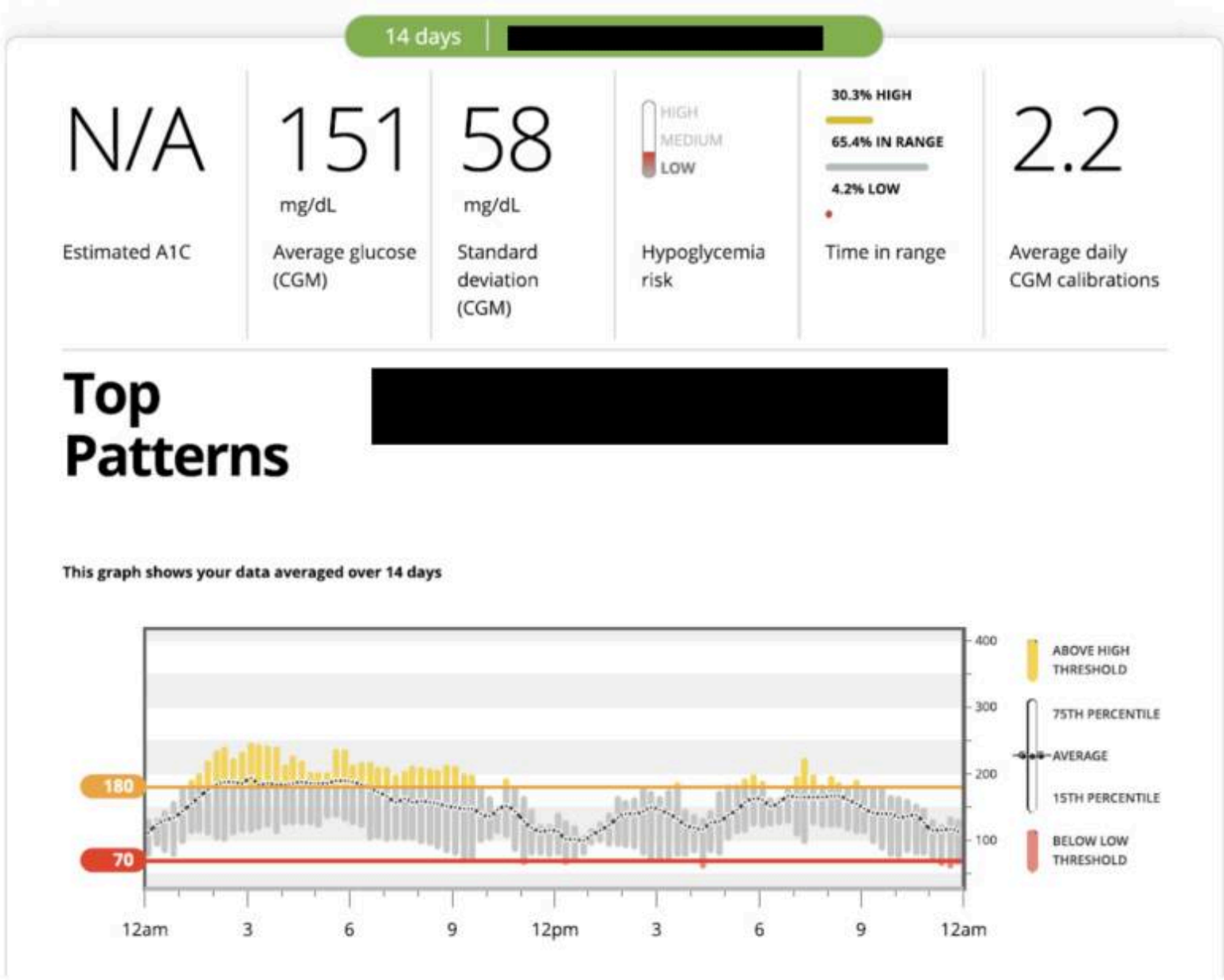


Artificial Pancreas

Type 1 diabetes occurs when the pancreas produces little or none of the insulin needed to regulate blood glucose

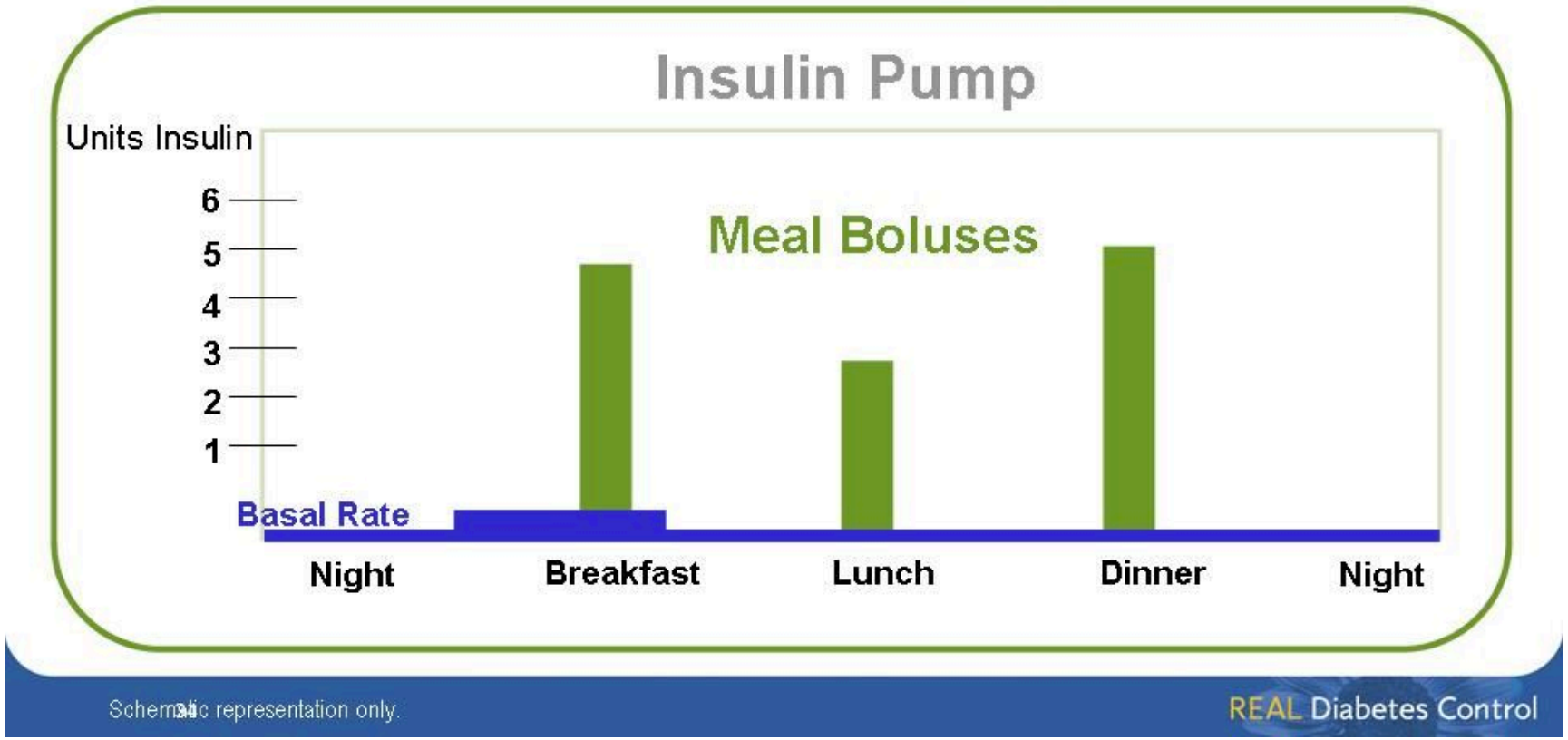
They rely on external administration of insulin to manage their blood glucose levels.

Continuous Glucose Monitoring

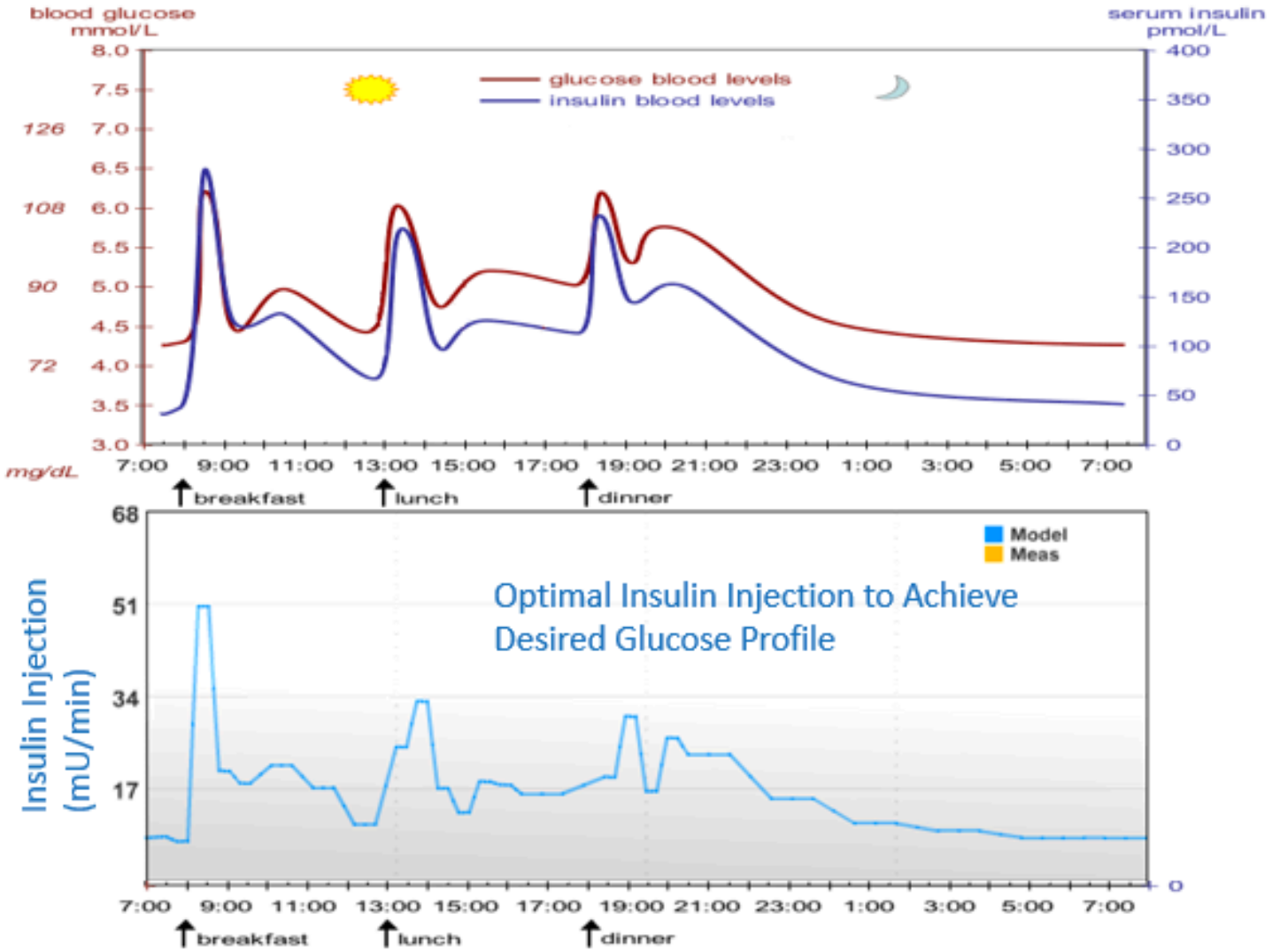


Insulin pumps

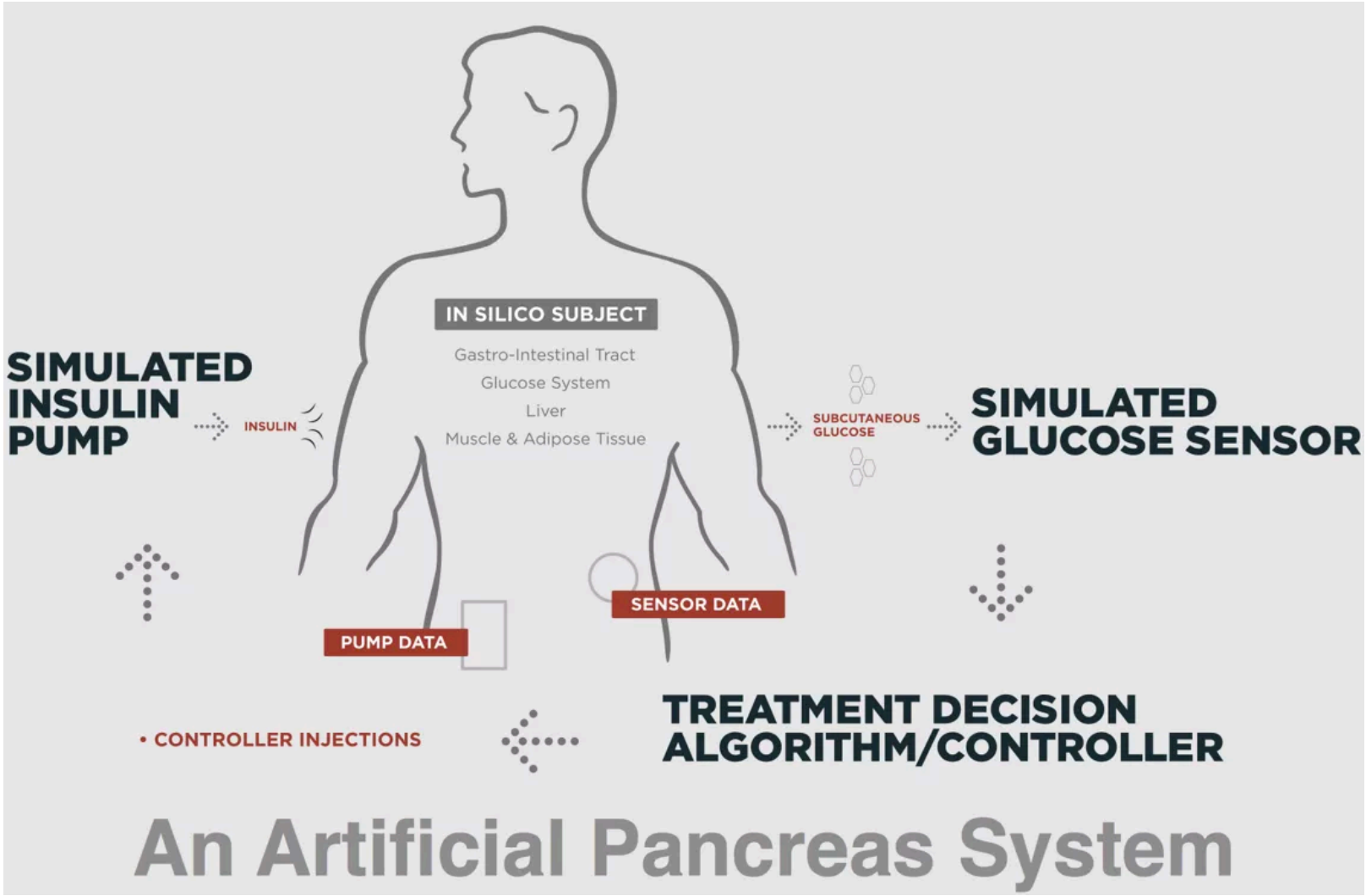
Carbohydrate counting matches your pre-meal bolus of insulin to the actual amount of food you plan to eat.



Artificial Pancreas



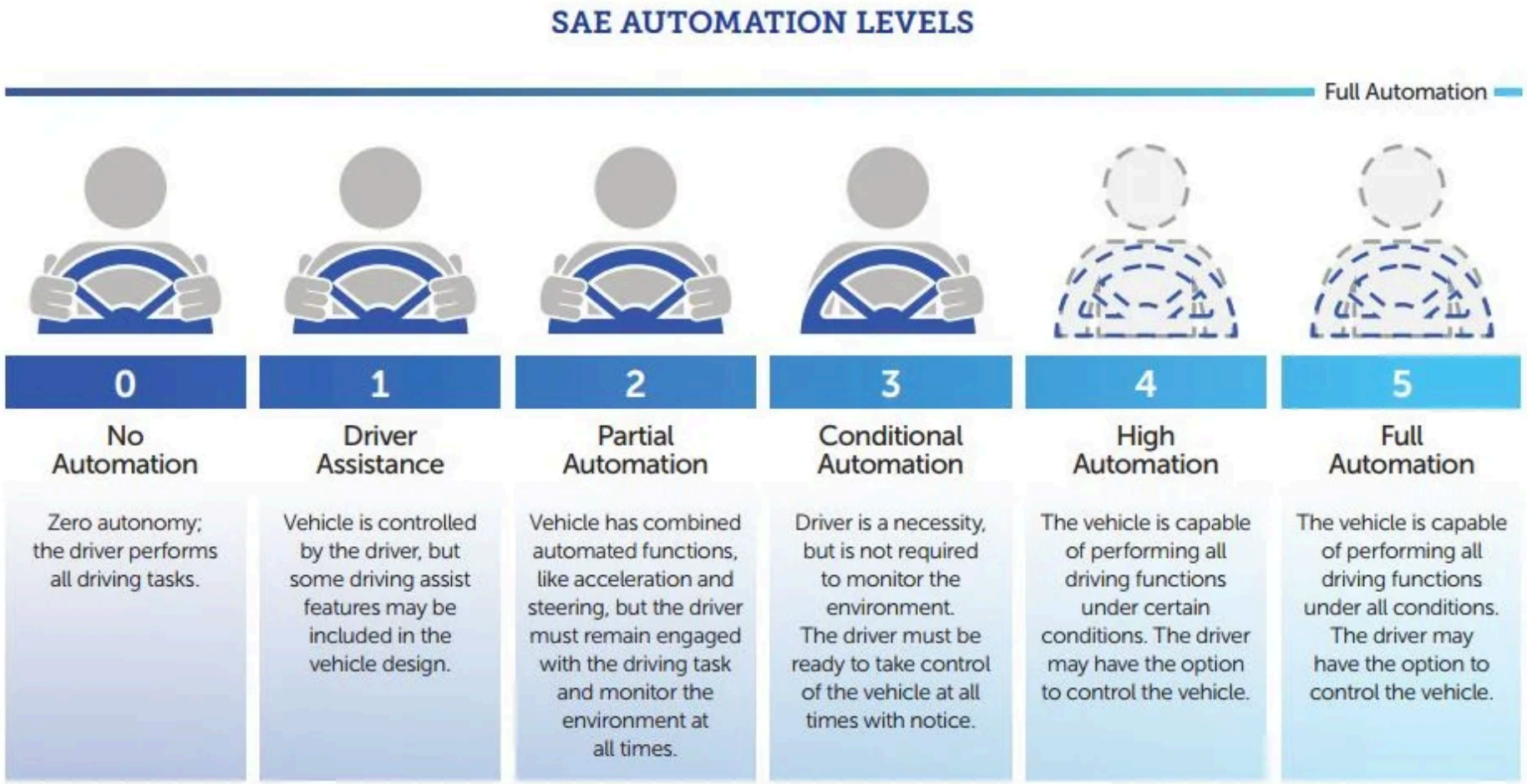
Artificial Pancreas



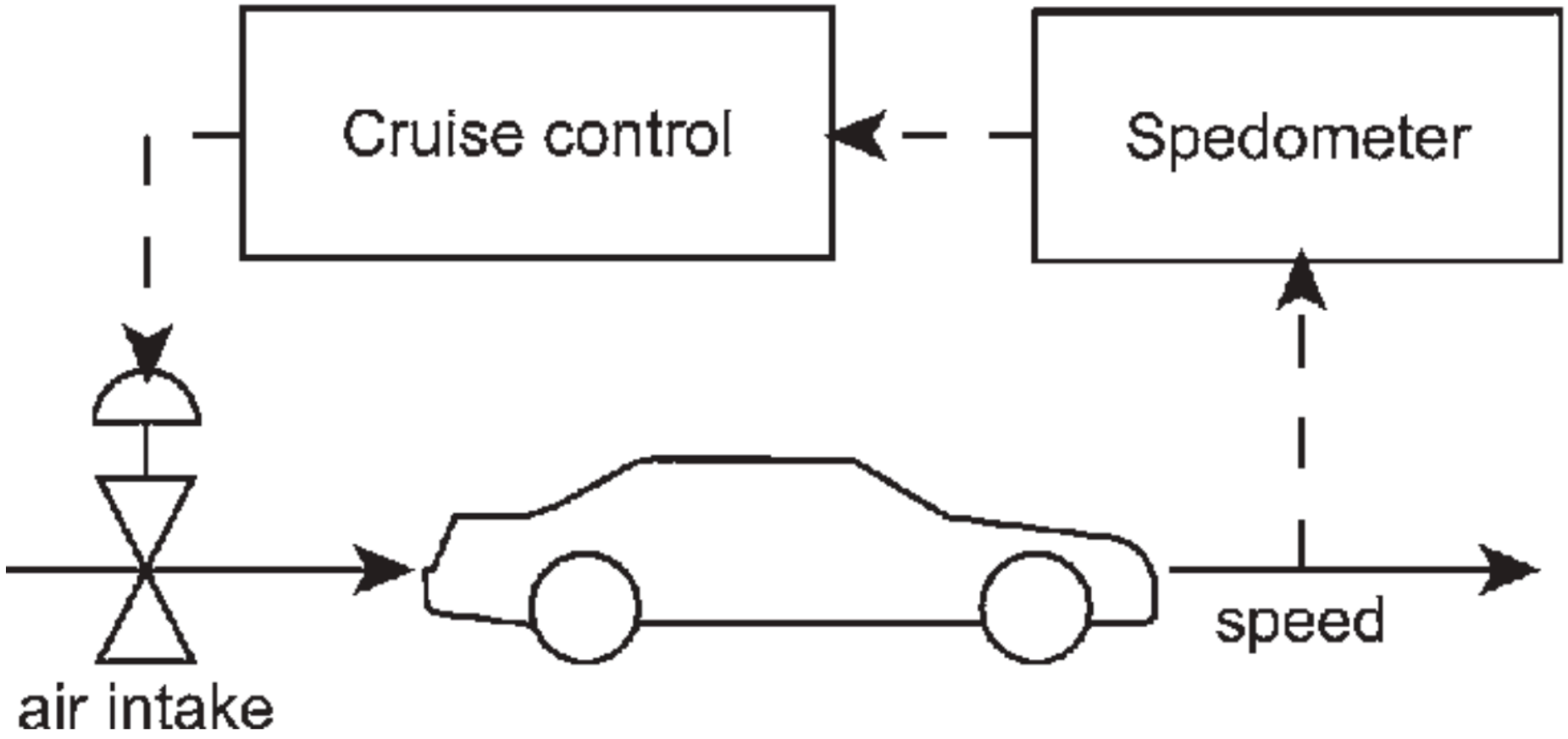
Transportation CPS

Everything that moves will become autonomous

Automotive Car



Automotive Car



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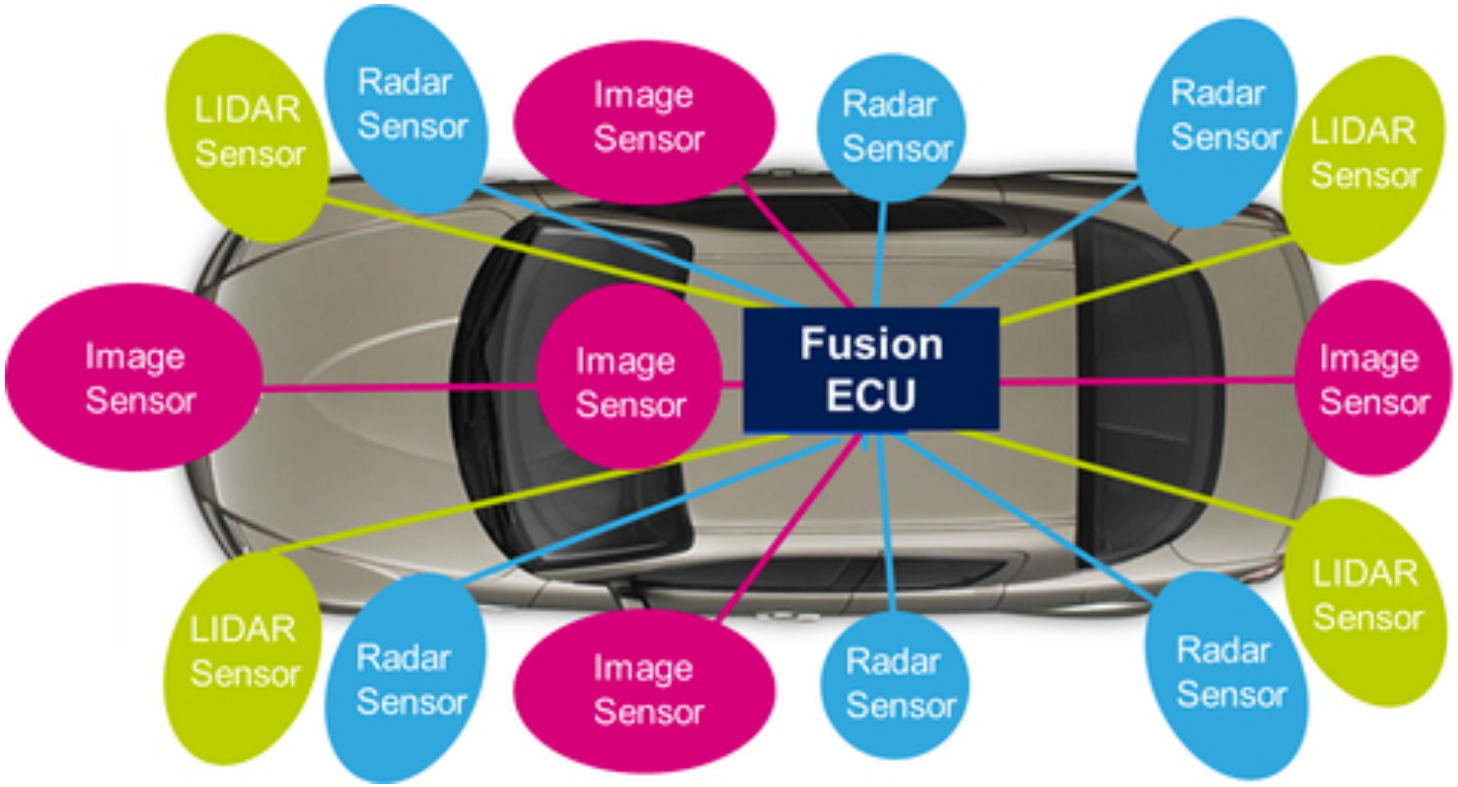
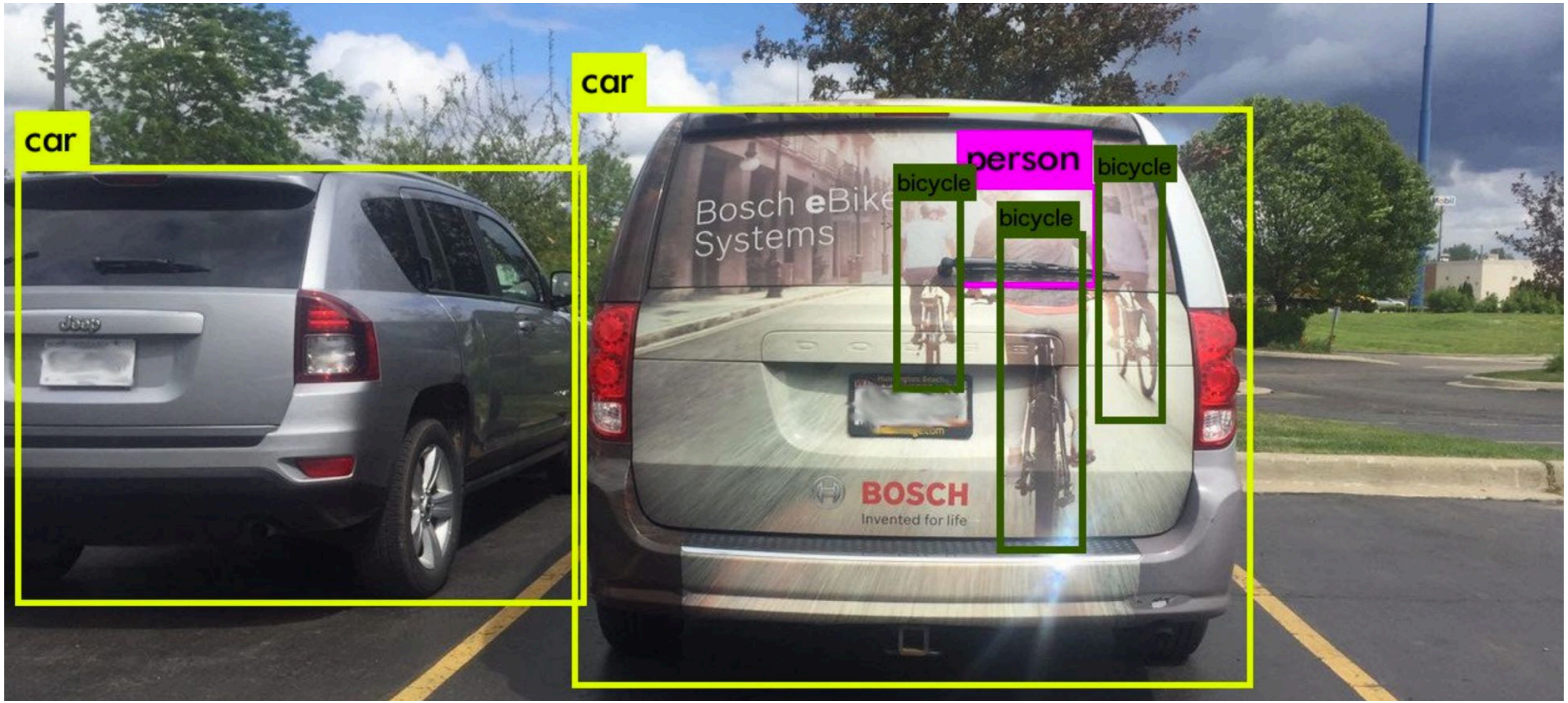
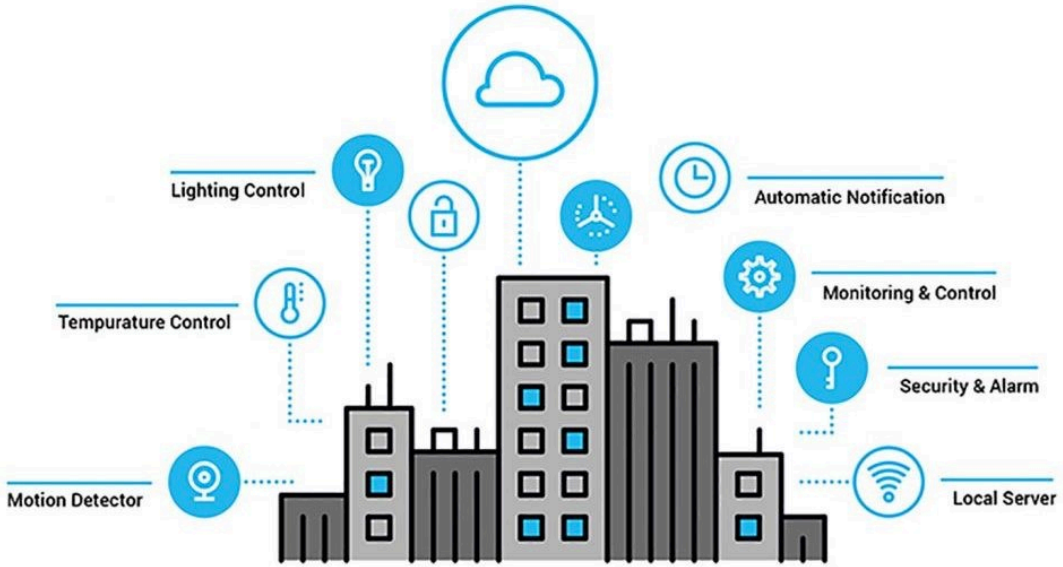


Automotive Car

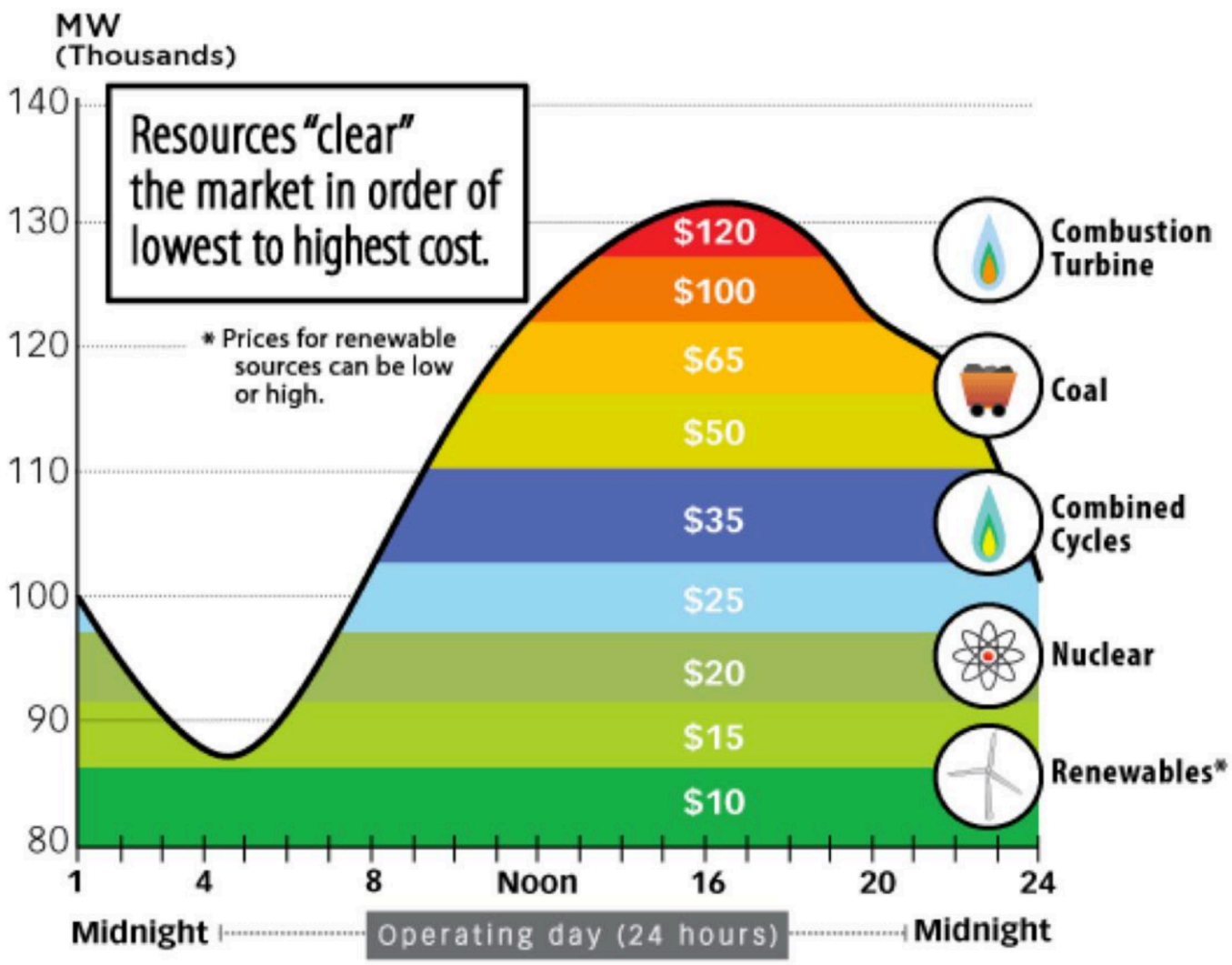


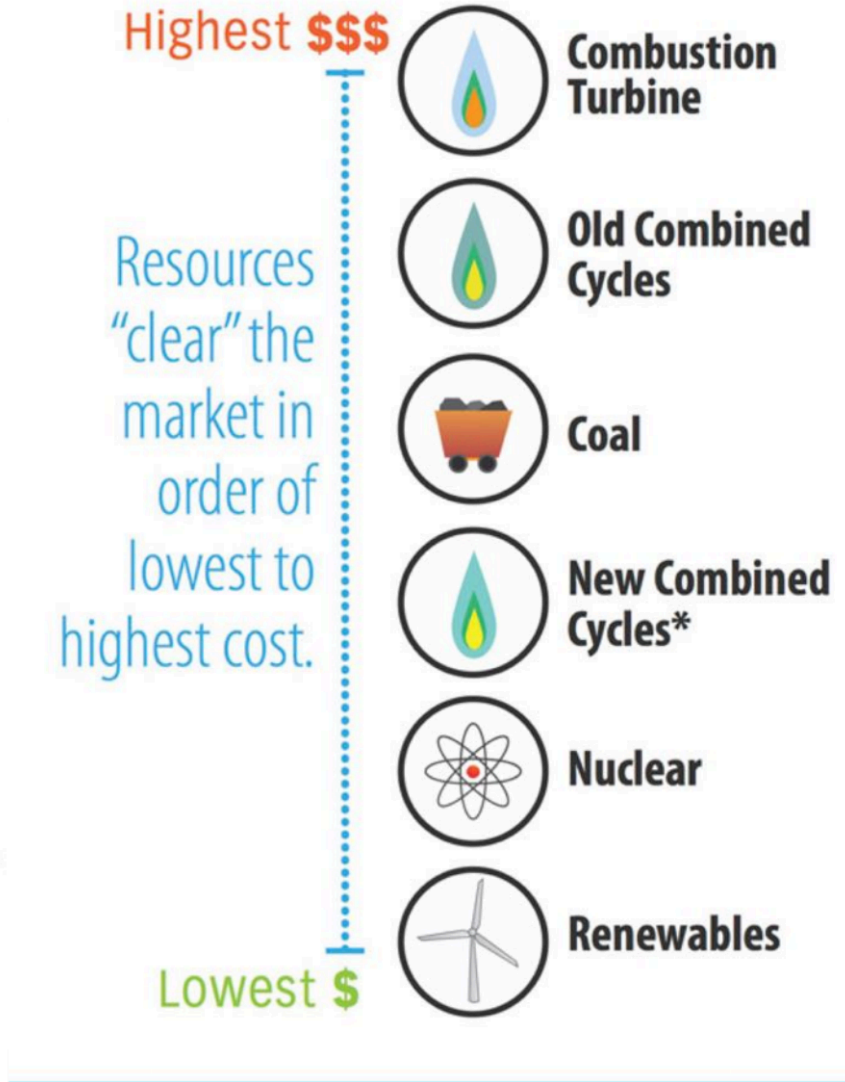
Energy


Lighting Control
Automatic Notification
Tempurature Control
Monitoring & Control
Security & Alarm
Motion Detector
Local Server

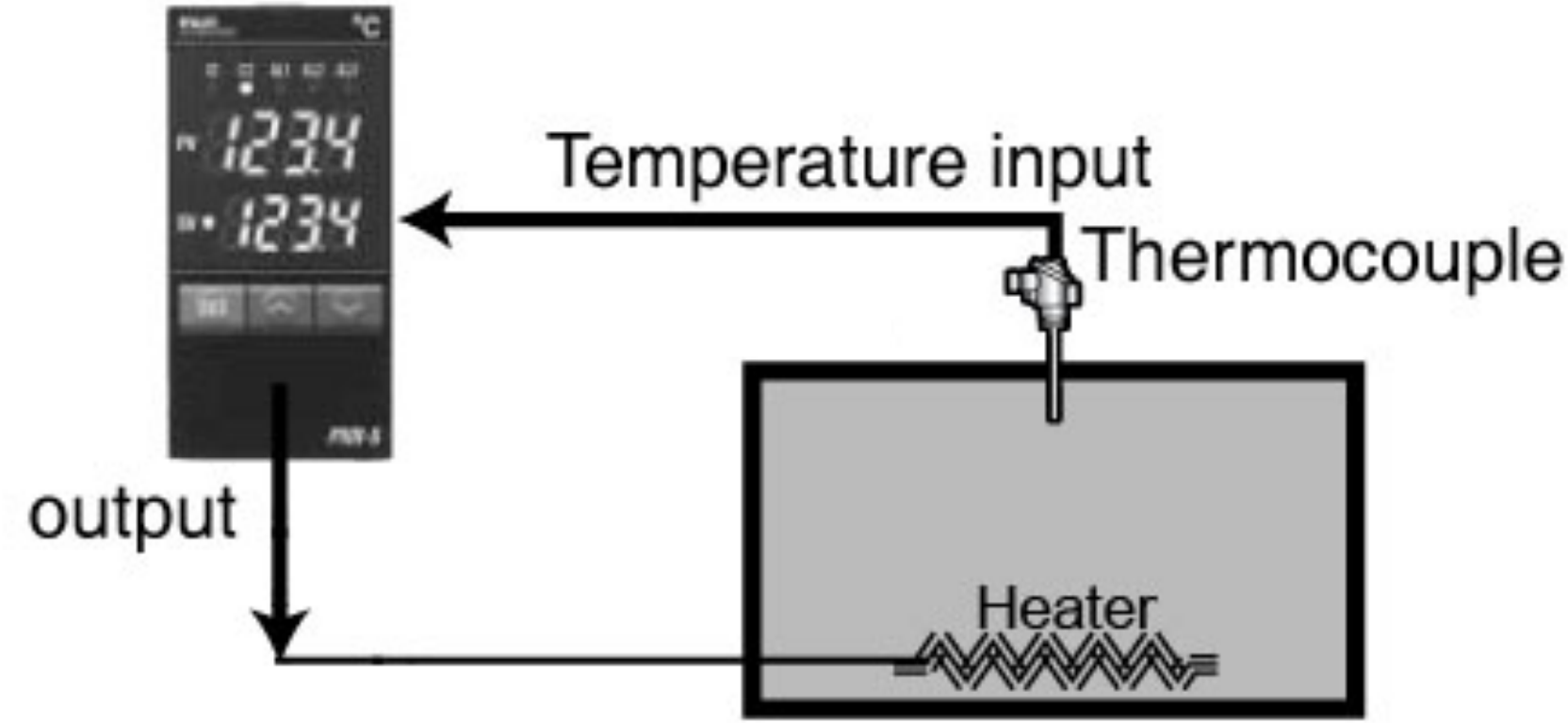

© Siemens

Energy Control



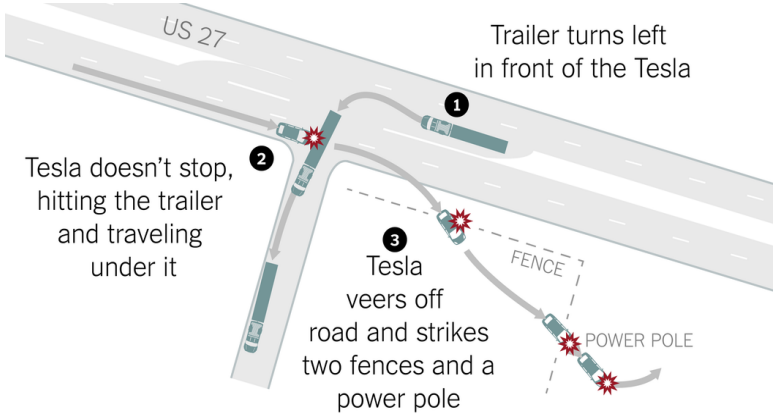


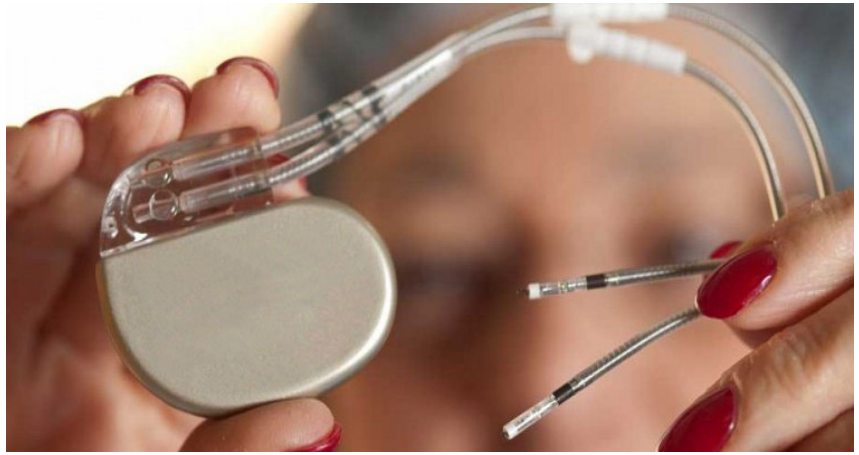
Temperature Control



Safety and/or Mission-Critical Systems

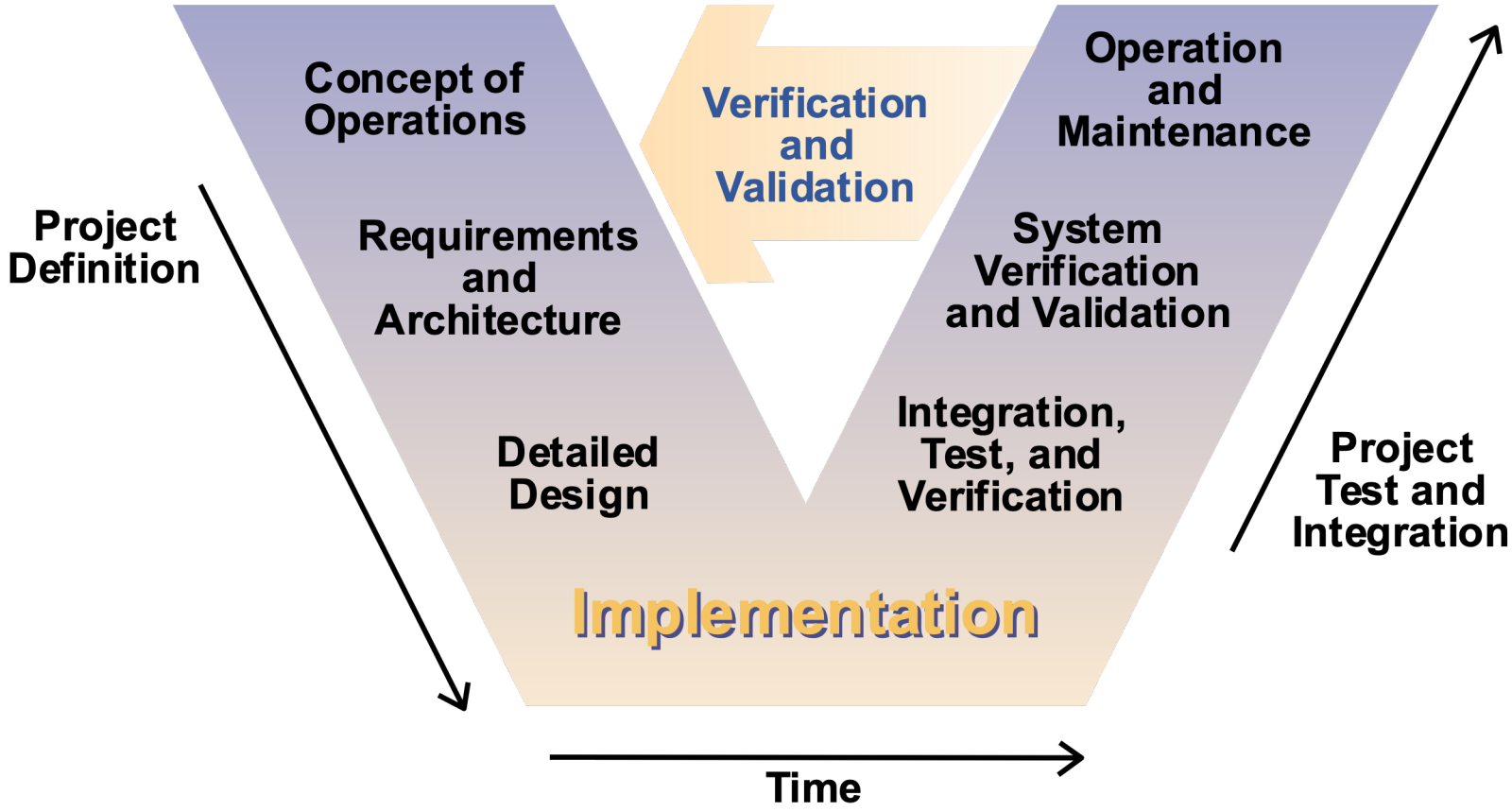
Systems whose failure or malfunction may severely harm people's lives, environment or equipment.





The **FDA** has issued **23 recalls of defective devices** during the first half of 2010, all of which are categorized as "Class I," meaning there is "**reasonable probability** that use of these products will cause serious **adverse health consequences** or **death**."

Model-based Design Approach



Validation : "Are you building the right thing?"

Verification : "Are you building it right?”

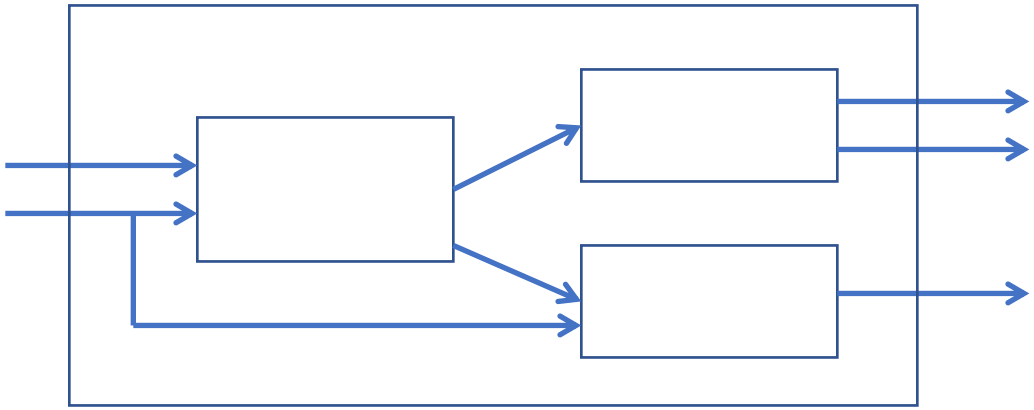
Model-based Design Approach

MDB when used for designing embedded software has 4 main steps:

1. Model the physical components/environment (also known as a plant model)
2. Analyze the plant, and synthesize/design the control-software at a high-level
3. Co-Simulate the plant and control-software
4. Automatically generate code from the control-software model for deployment

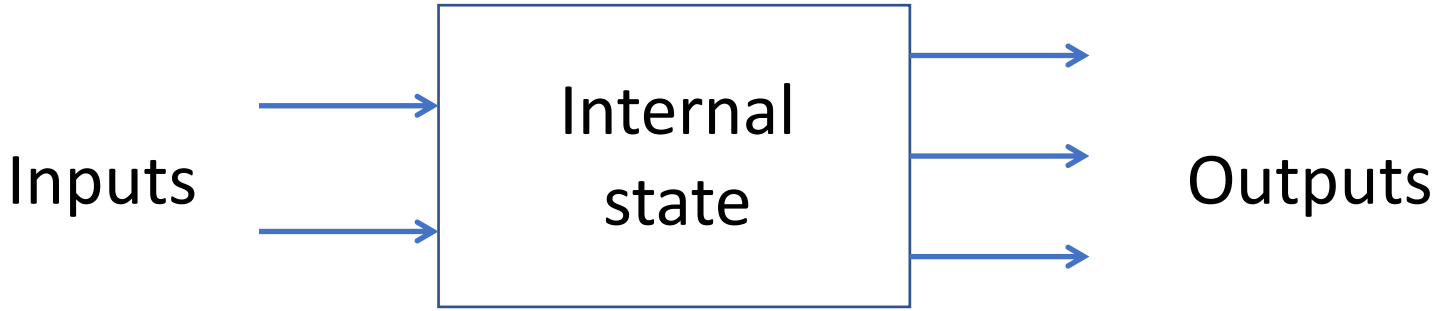
Model-based Design Approach

MBD languages are often visual and block-diagram based, e.g. Simulink



Reactive Component

Most convenient model of computation for an (Autonomous) CPS is a ***reactive and concurrent model of computation.***



An autonomous CPS can be viewed as a ***network of components*** *that communicate either* ***synchronously*** *or* ***asynchronously.***

Models: abstractions of system dynamics

Examples of type of modeling that for CPS components:

- Modeling physical phenomena – differential equations
- Feedback control systems – time-domain modeling
- Modeling modal behavior – FSMs, hybrid automata, …
- Modeling sensors and actuators – models that help with calibration, noise elimination,
- Modeling hardware and software – capture concurrency, timing, power, …
- Modeling networks – latencies, error rates, packet loss,