# AirborneCPS: A Simulator for Functional Dependencies in Cyber Physical Systems

## A Traffic Collision Avoidance System Implementation

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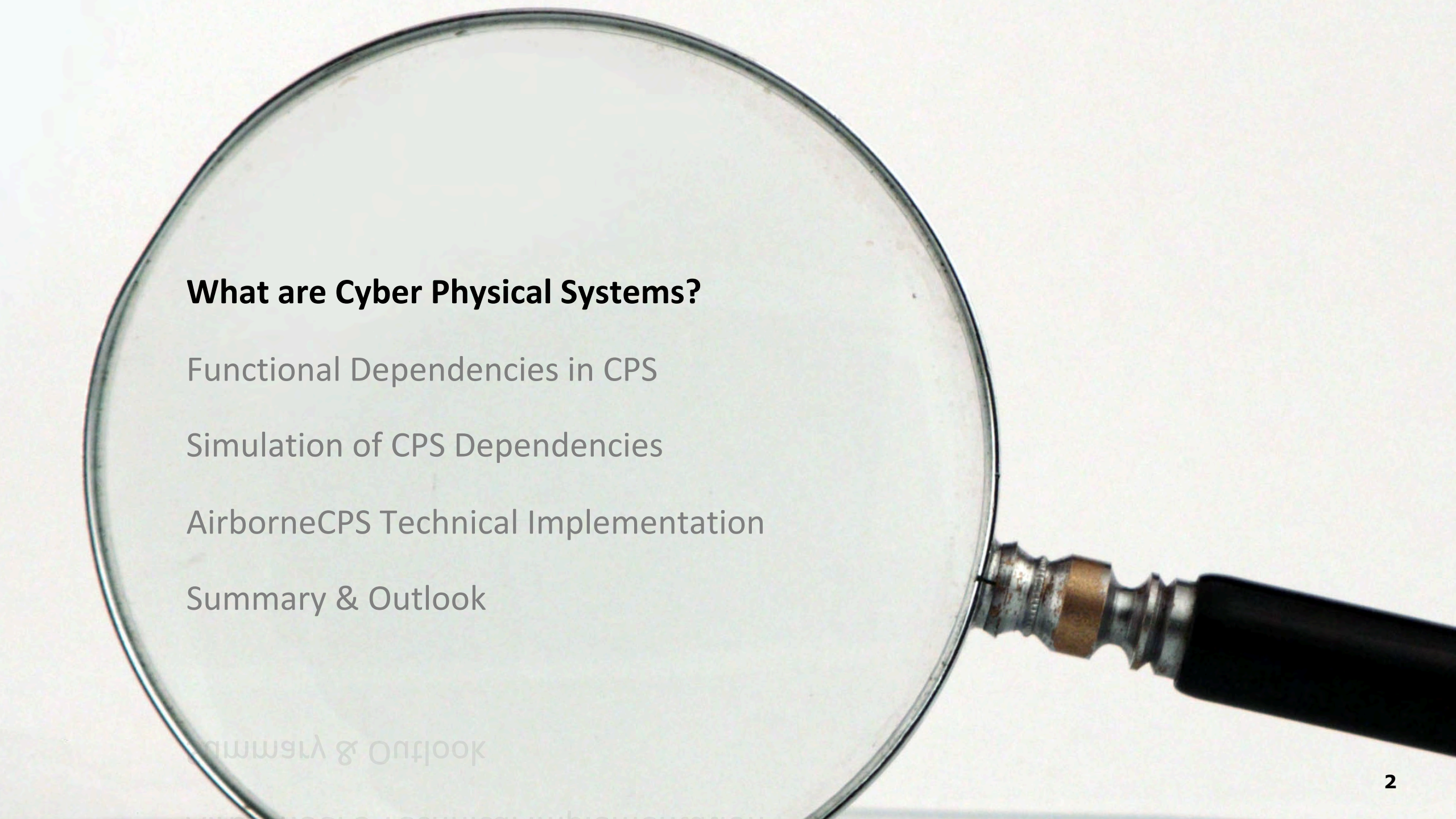


**What are Cyber Physical Systems?**

Functional Dependencies in CPS

Simulation of CPS Dependencies

AirborneCPS Technical Implementation

Summary & Outlook

Cyber Physical Systems (CPS) are a **"novel" system type**.

CPS monitor physical values with **sensors** and act upon them using **actuators** like Embedded Systems.

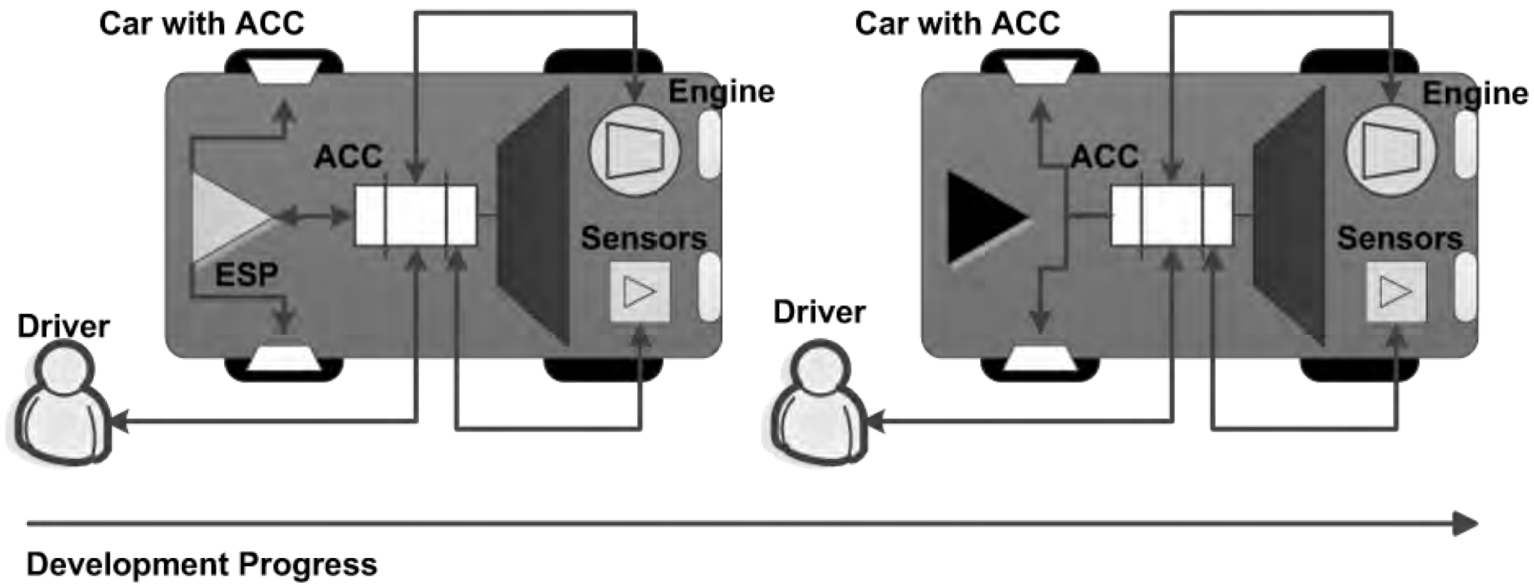
CPS **communicate** with other systems like "*Internet-of-Things*"-things.

CPS **achieve a common goal** that each individual system cannot achieve on its own.

We call this **functionally dependent CPS**.

# Comparison to Embedded Systems

An Adaptive Cruise Control (ACC) maintains safe speed and distance to a vehicle ahead.




Suppliers build ES with OEMs in mind. **With a specific context in mind**.
Once the ES is deployed, the **context will never change**.

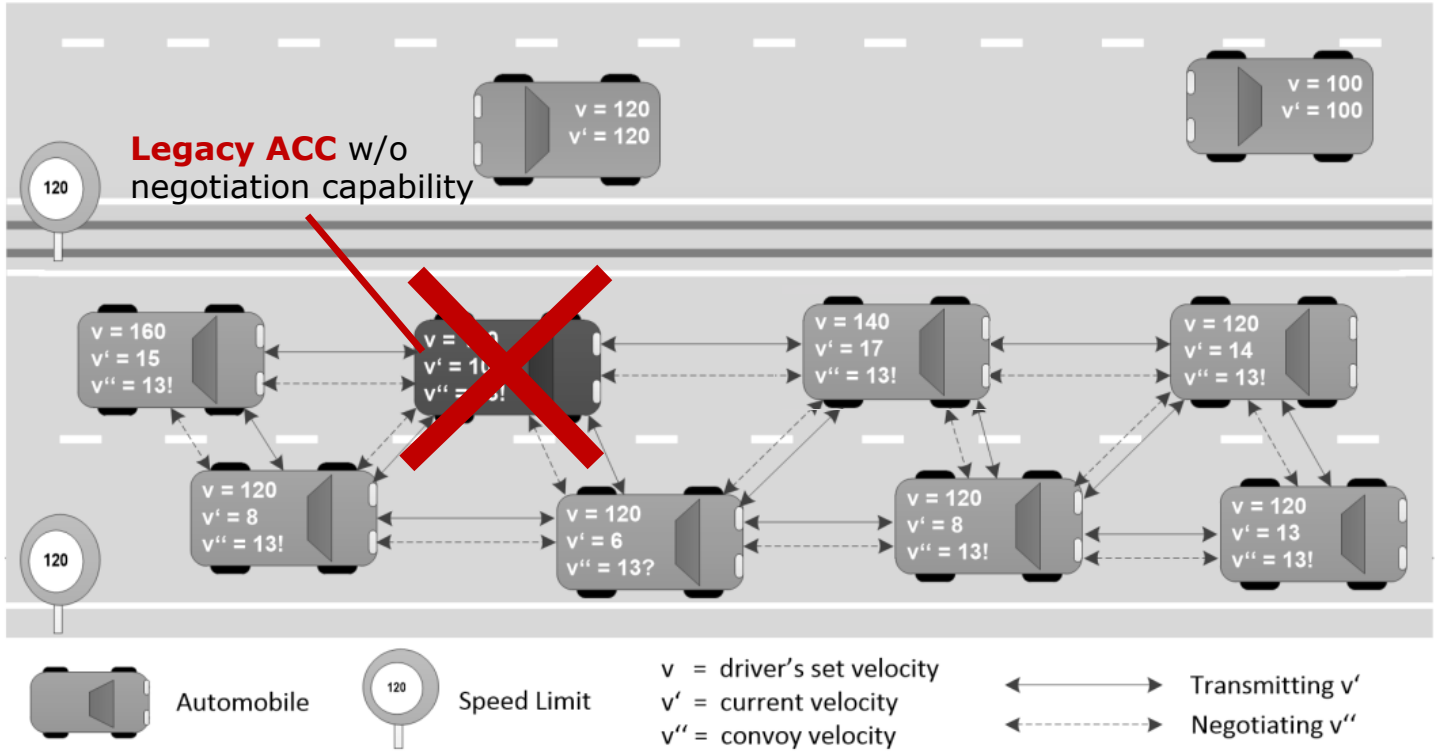
**Assumptions** are made but **fail in case of dynamic functional dependence**.

# Functional Dependence at Runtime

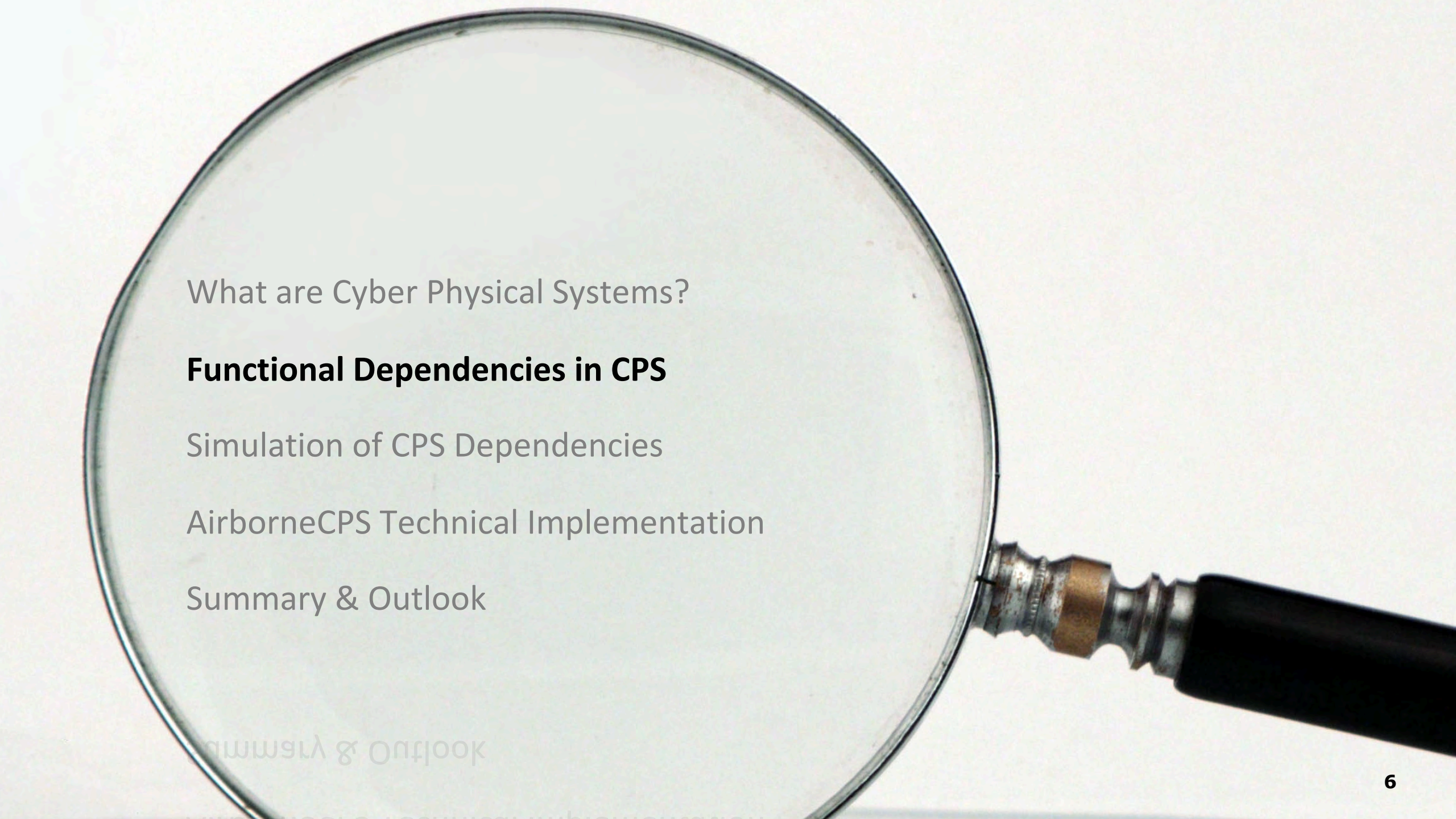
The Collaborative Adaptive Cruise Control (CACC) **communicates** with other CACCs to **negotiate speed** to **optimize traffic flow**.

Runtime interactions **cannot** easily **be predicted at design time**:

- which **type and model** of ACC is another vehicle equipped with?
- **Is** that ACC **collaborative** (or possibly some **legacy** system)?
- Are the communication protocols **safely compatible**?
- **What if the driver** choses to ignore the CACC or **does something stupid**?




**Open Contexts, Runtime Adaptiveness, and Human-in-the-Loop interaction pose issues for development.** To investigate this, we will simulate runtime behavior.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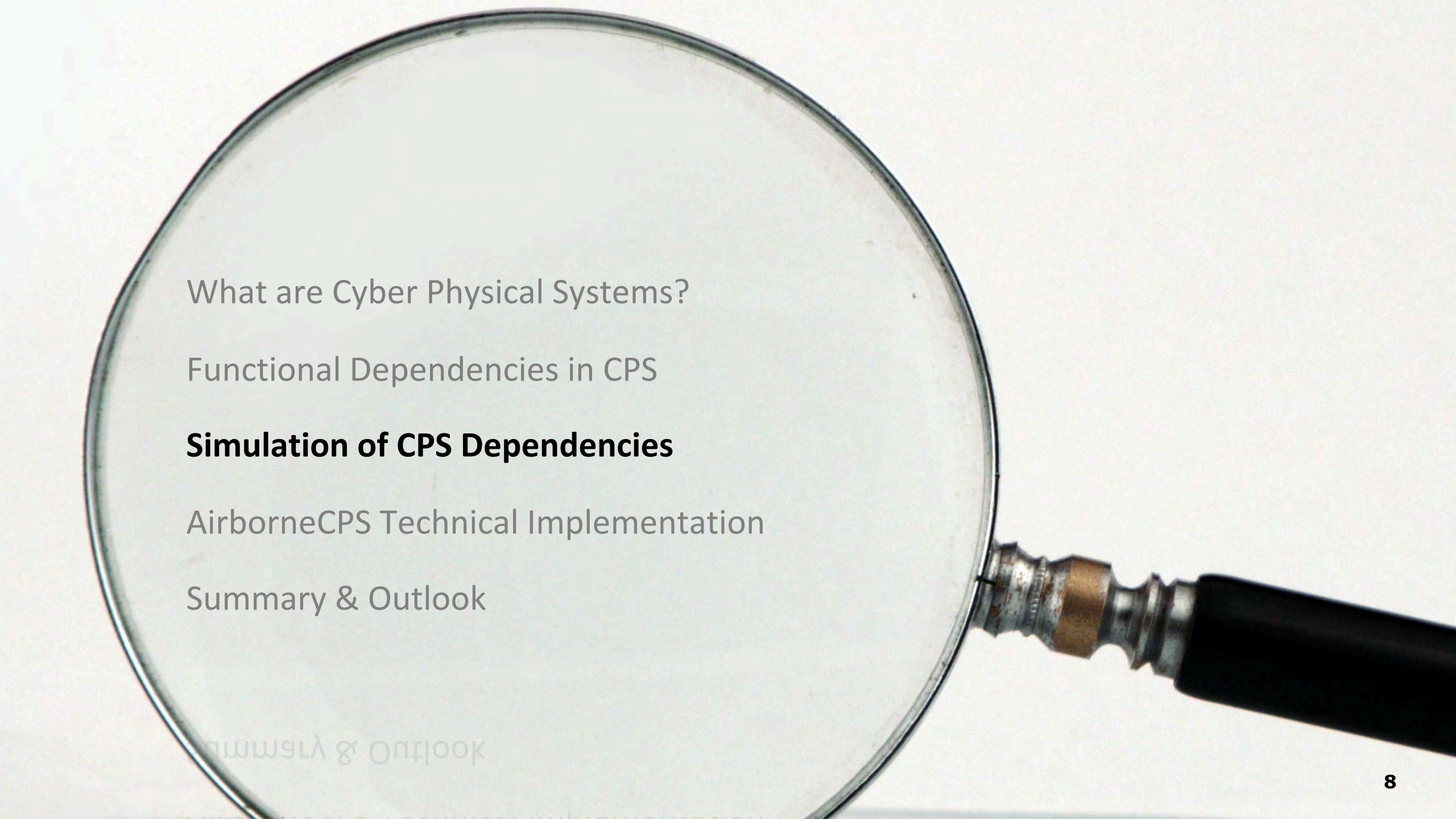
# Functional Dependence Types in CPS:

(according to [3, 15])

| | Static | Dynamic |
|---|---|---|
| **Homogeneous** | The CPS network is composed of a **fixed number of individual CPS** and each CPS has a **known feature set**.<br><br>***Example:***<br>**prosumer architectures** [16]. | The CPS network forms **new connections at runtime** with nodes possessing a **known feature set**.<br><br>***Example:***<br>**automated traffic regulation** [17]**, smart cities** [18]. |
| **Heterogeneous** | The CPS network is composed of a **fixed number of individual CPS**, but the individual CPS devices have **different feature sets**.<br><br>***Example:***<br>**Industry-4.0-applications, IoT** [19]. | The CPS network forms **new connections at runtime** with nodes possessing an **unknown feature set**.<br><br>***Example:***<br>**CACC** [4, 5], **TCAS**. |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# Case Example: Traffic Collision Avoidance System

***Purpose:***
Detect other aircraft on collision course, warn crew, and compute evasive action.

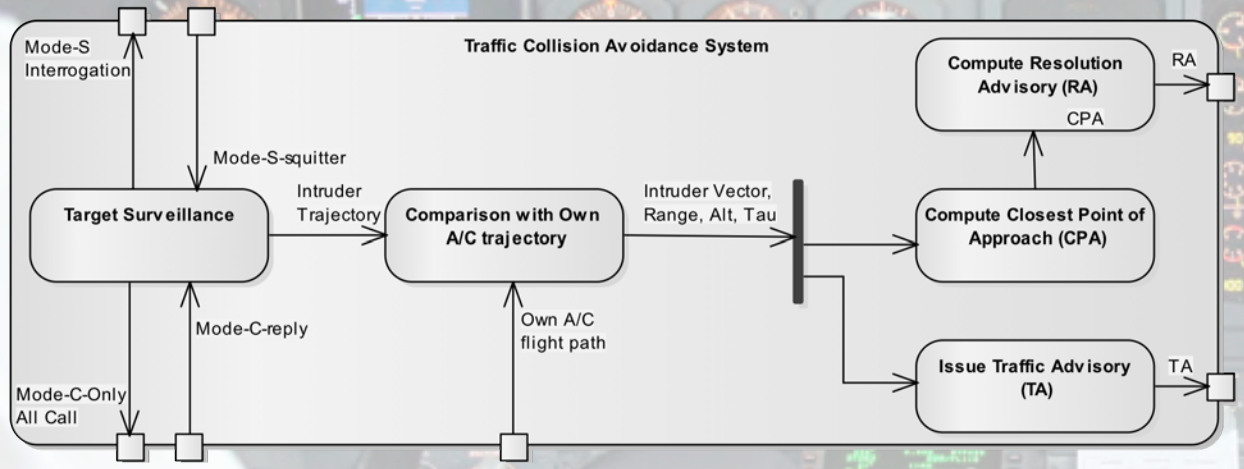



Image: Rogerson Aircraft Corporation.

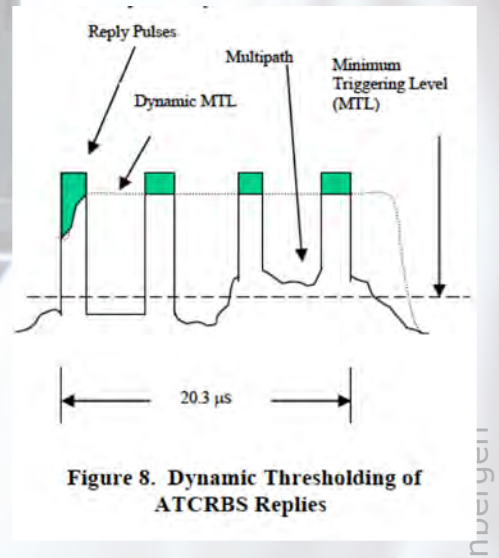




**Figure 8. Dynamic Thresholding of ATCRBS Replies**


Image: Laminar Research, Inc.

***Why TCAS?***

- Airborne **collision avoidance implies functional dependency**
- As **aircraft types differ**, so do **TCAS implementations**
- **Standardization**, but it only goes so far
- Readily **available simulation platform**, easily extendable
- We can **simulate all types of functional dependence**…

The range between the aircraft at any time $t$ is given by[a]

$$r(t) \equiv \|\mathbf{s}(t)\| = \sqrt{\|\mathbf{s}\|^2 + 2t\mathbf{s}\cdot\mathbf{v} + t^2\|\mathbf{v}\|^2}.$$

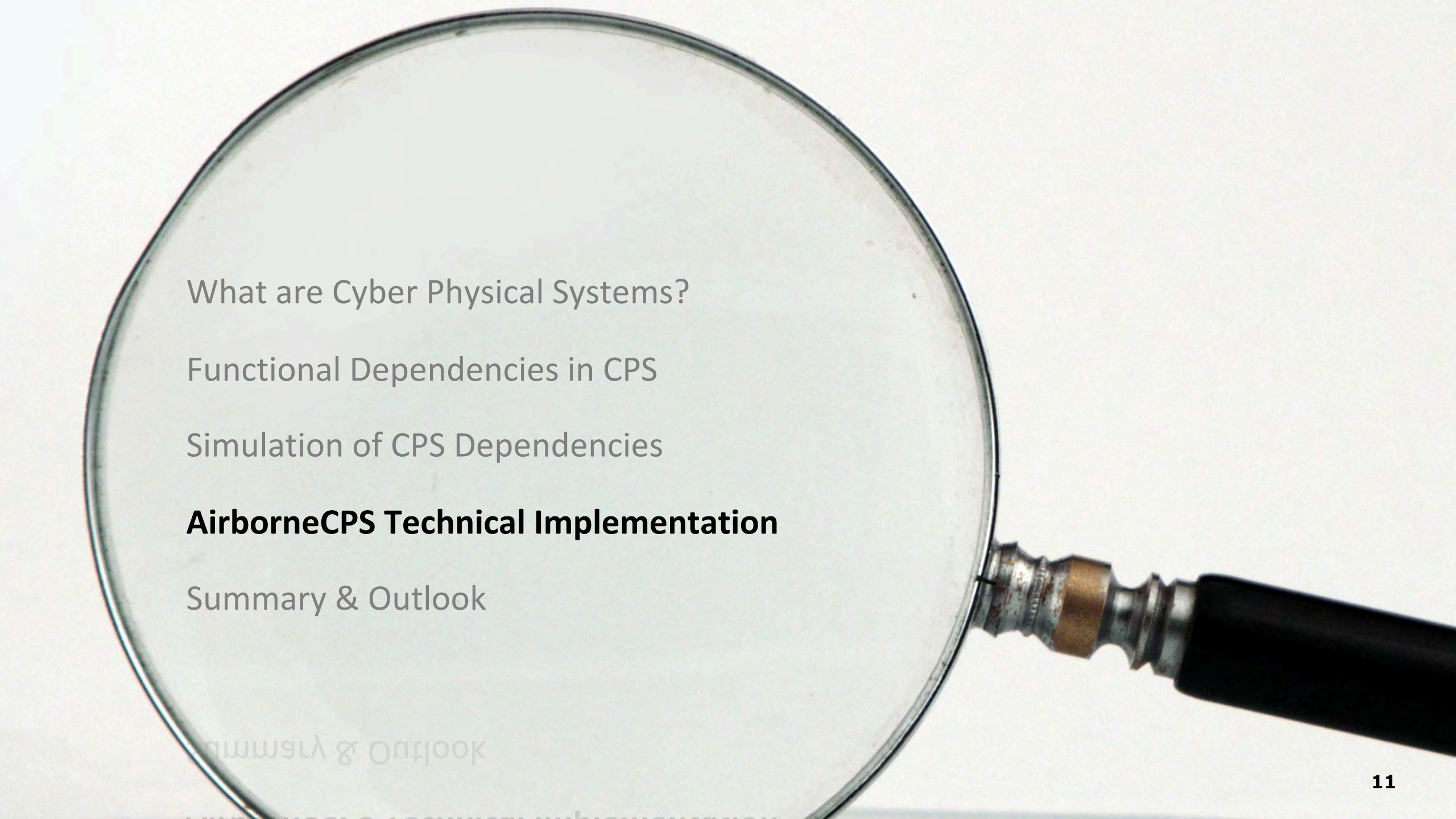
Closure rate is the derivative of $r(t)$ with respect to $t$, i.e.,

$$\dot{r}(t) \equiv \frac{\mathbf{s}\cdot\mathbf{v} + t\|\mathbf{v}\|^2}{\|\mathbf{s}(t)\|}.$$

# Simulating Functional Dependence

| | Static | Dynamic |
|---|---|---|
| **Homogeneous** | **Multiple TCAS equipped aircraft** enter each other's protection volume during flight.<br><br>***Example:***<br>**Random traffic threat during climb or descending flight.** | All TCAS are of the **same type** and **a known number of aircraft** participate in the collision scenario.<br><br>***Example:***<br>**Multiple autonomous drones fly in formation.** |
| **Heterogeneous** | Multiple aircraft enter each other's protection volume, but **some aircraft are not TCAS equipped**.<br><br>***Example:***<br>**Private plane with TCAS encounters an ultra-light plane.** | **Multiple aircraft** equipped with TCAS are interacting with **one aircraft without TCAS**.<br><br>***Example:***<br>**Military aircraft intercept and escort a hostile intruder.** |

We can **simulate all types of functional dependence.**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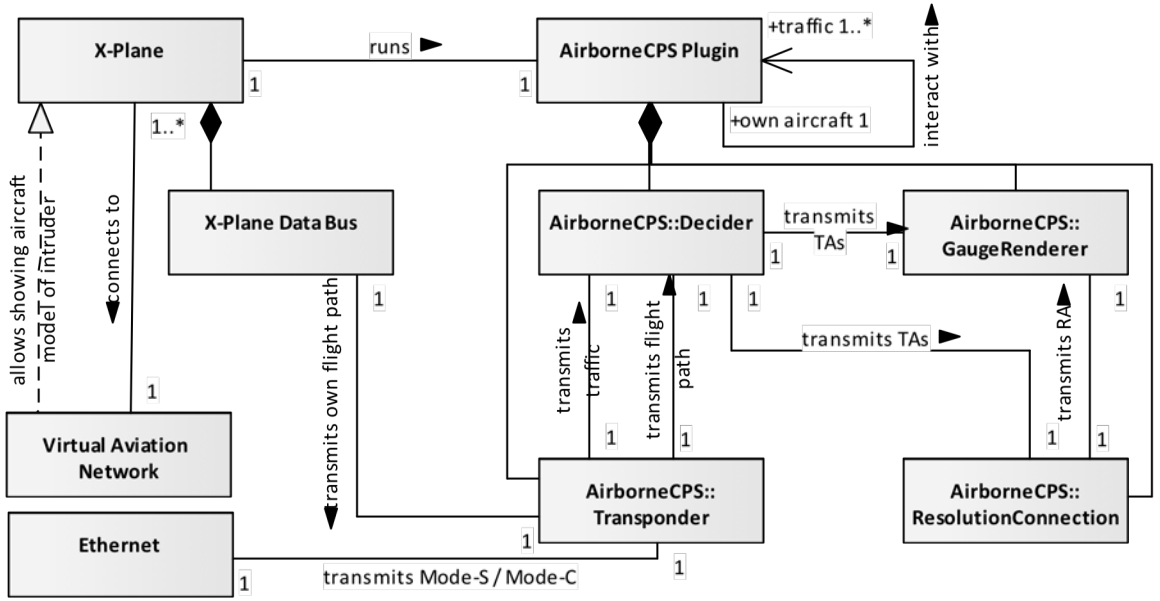


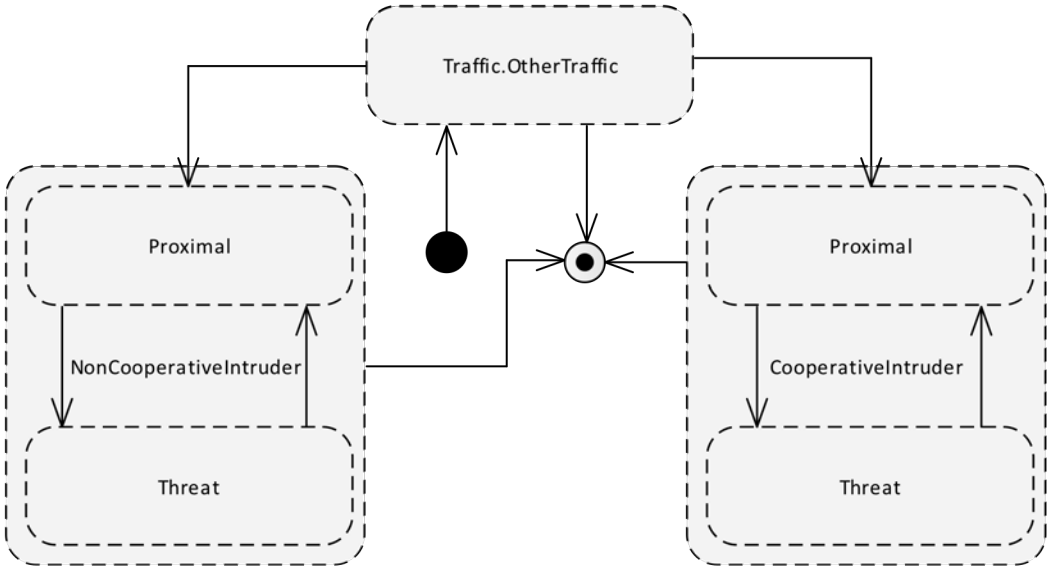



**Code Github: https://bit.ly/2rZfMA6**



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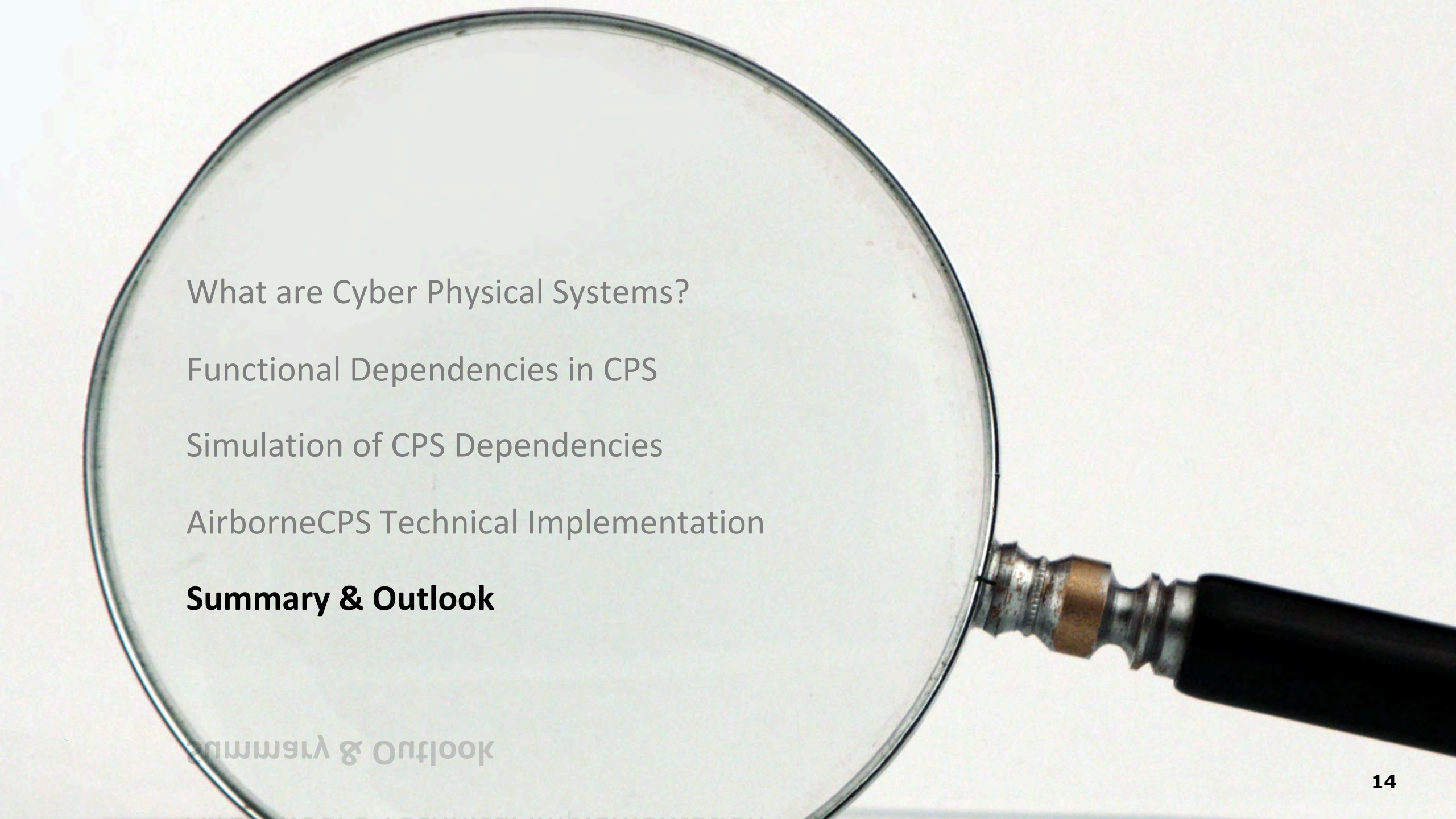
Youtube Channel:
https://bit.ly/2J9EaZJ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## Cyber-Physical Systems operate in an open world

CPS operate in the real world, which constantly changes, e.g., through dynamic network allocation.

## Functional Dependencies in CPS Networks

homogeneous vs. heterogeneous /\ dynamic vs. static

## How can **Functional Dependencies** be **leveraged** at design time and **predicted** at runtime?

## AirborneCPS is a free simulation tool

to aid identification of undesired functional dependencies at runtime by simulating different interaction scenarios… **but it's work in progress.**

**Videos on Youtube: https://bit.ly/2J9EaZJ**
**Code Github: https://bit.ly/2rZfMA6**

# Thanks for your Attention

and

# Feel Free to Ask Stuff


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