Platooning LEGOs:
An Open Physical Exemplar for Engineering Self-Adaptive Cyber-Physical Systems-of-Systems

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Platooning : Collaborative Autonomous Vehicles

○ **Adaptive Cyber-Physical Systems**

Environment monitoring
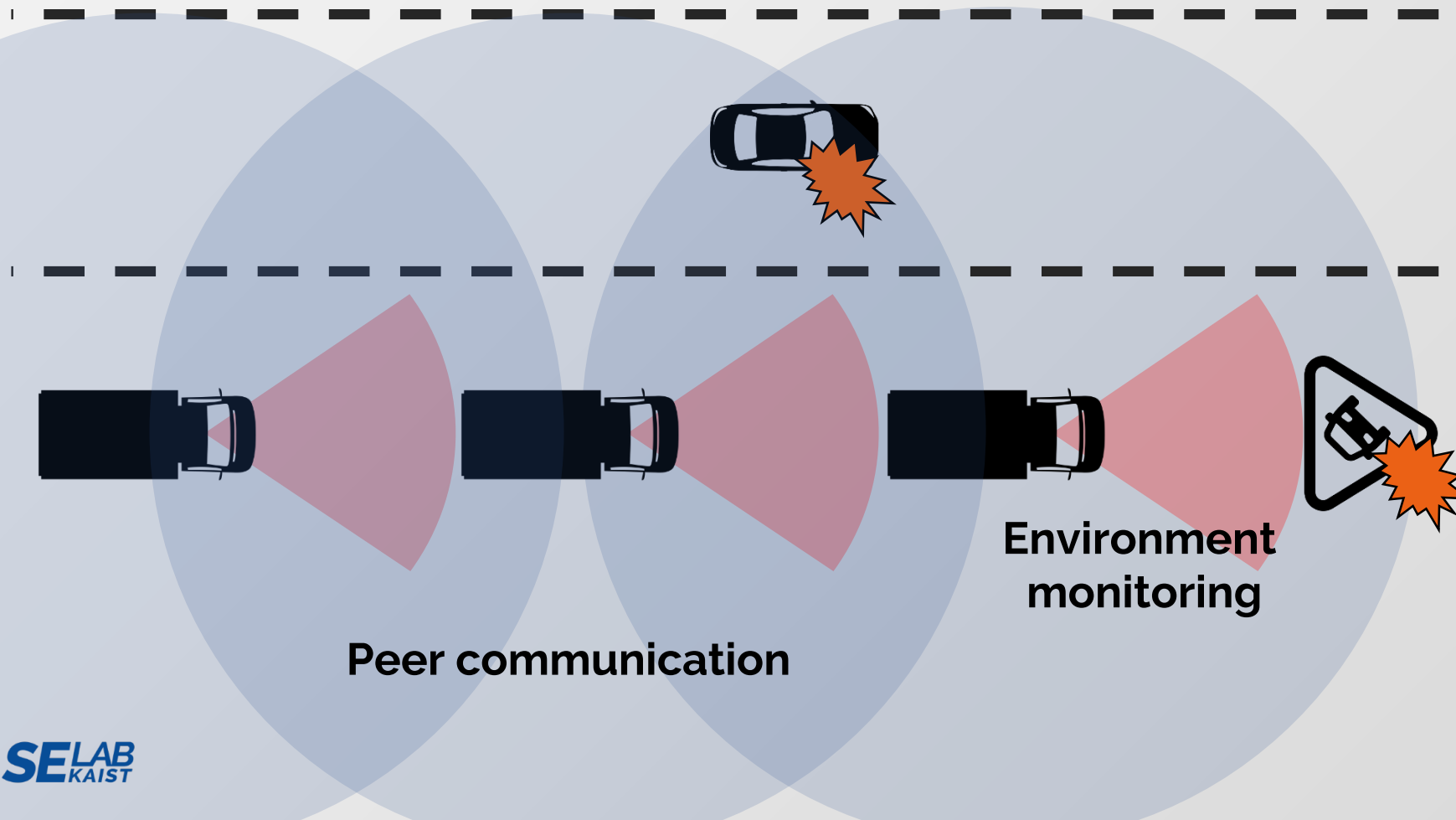
Individual goals
- Collision prevention
- Travel speed maximization

Platooning : Collaborative Autonomous Vehicles

- **Adaptive Cyber-Physical Systems-of-Systems (CPSoS)**

Individual goals
- Collision prevention
- Travel speed maximization

Collaborative goals
- Driving in a row
- Road occupancy minimization

Environment monitoring

Peer communication

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Difficulties of Engineering CPSoS

Huge cost

Requiring high mechanical knowledge

Safety risks

Real experiment

VS

Low reality

Limited expressions of environmental uncertainties

Simulation-based experiment

Our solution: Semi-realistic experimental environment using programmable LEGO

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Purpose of *Platooning LEGOs*

- **A CPSoS Exemplar**
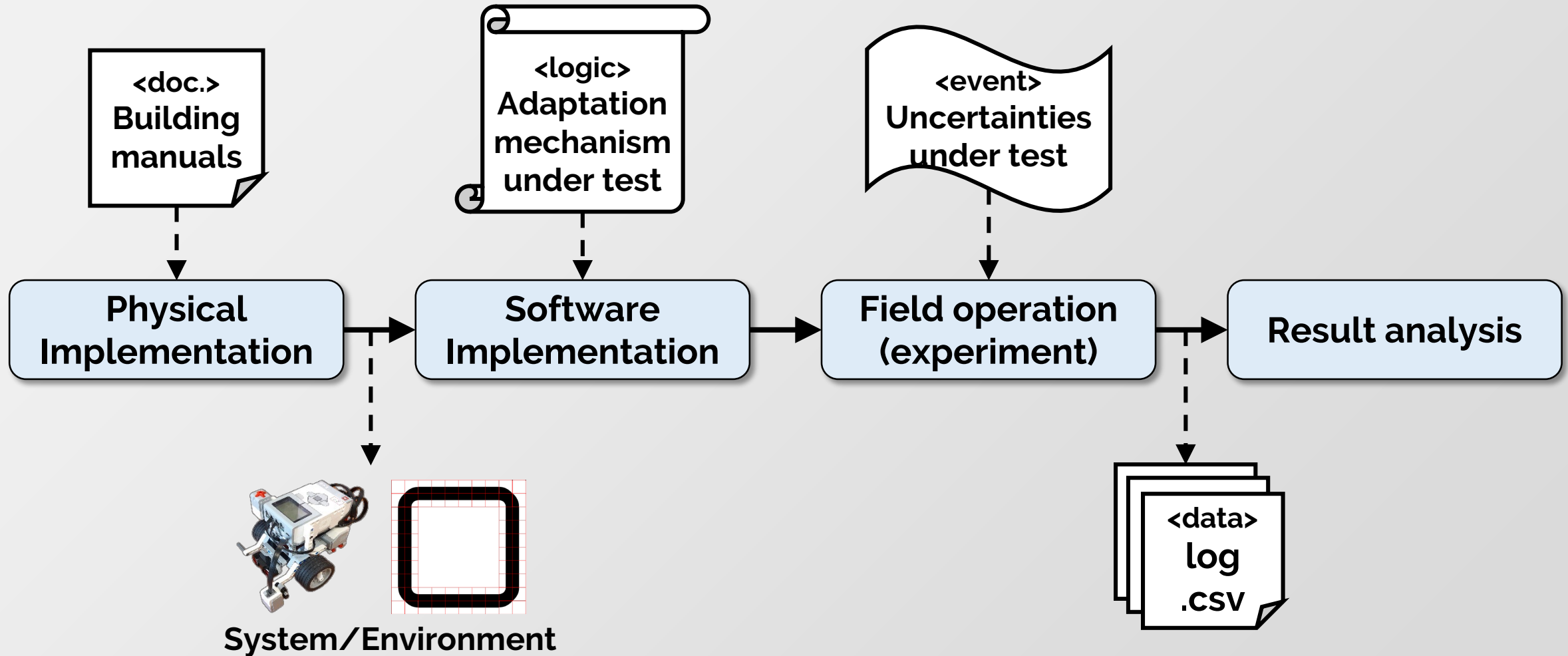 - an **industrial adaptation model problem** representing both **CPS** and **SoS**

- **A Physical Exemplar**
  - experimental environment producing **real data** from **physical sensors and actuators**

- **An Open Exemplar**
  - **easy-to-build** experimental environment for every self-adaptive system researcher
  - **cheap** physical experimental environment

CPSoS Experiment Process using *Platooning LEGOs*

<doc.> Building manuals

<logic> Adaptation mechanism under test

<event> Uncertainties under test

Physical Implementation

Software Implementation

Field operation (experiment)

Result analysis

System/Environment

<data> log .csv

LEGOlization : Autonomous Vehicles

Monitor → **Analyze** → **Plan** → **Execute**

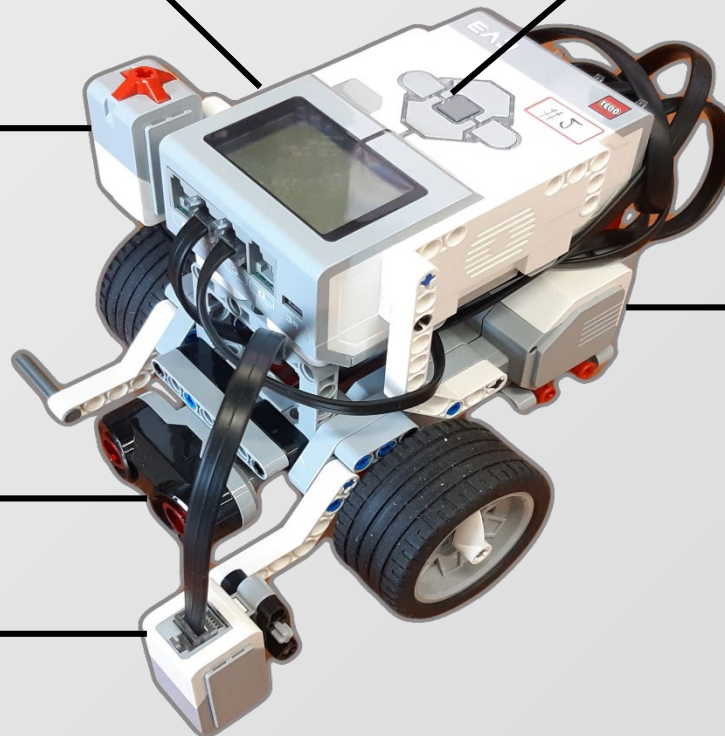**Bluetooth**
(peer's situation)
- text, float, bool, etc.

Button (Driver's
manual command)
- Boolean

Ultrasonic sensor
(obstacle detection)
- cm

Color sensor
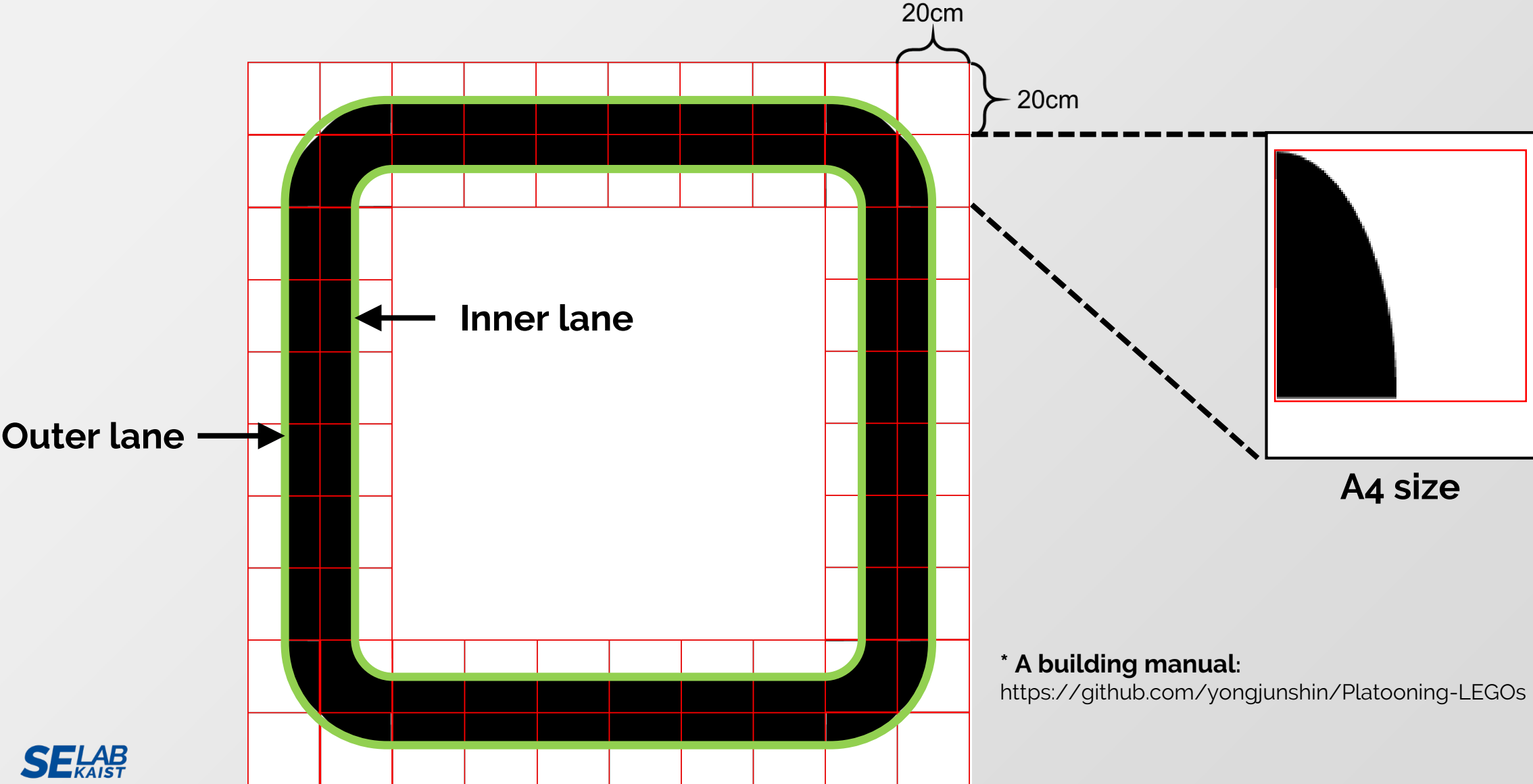(road tracking)
- RGB or Gray-scale

EV3 brick
(adaptation logic
computation,
data logging)
- Python

Motors
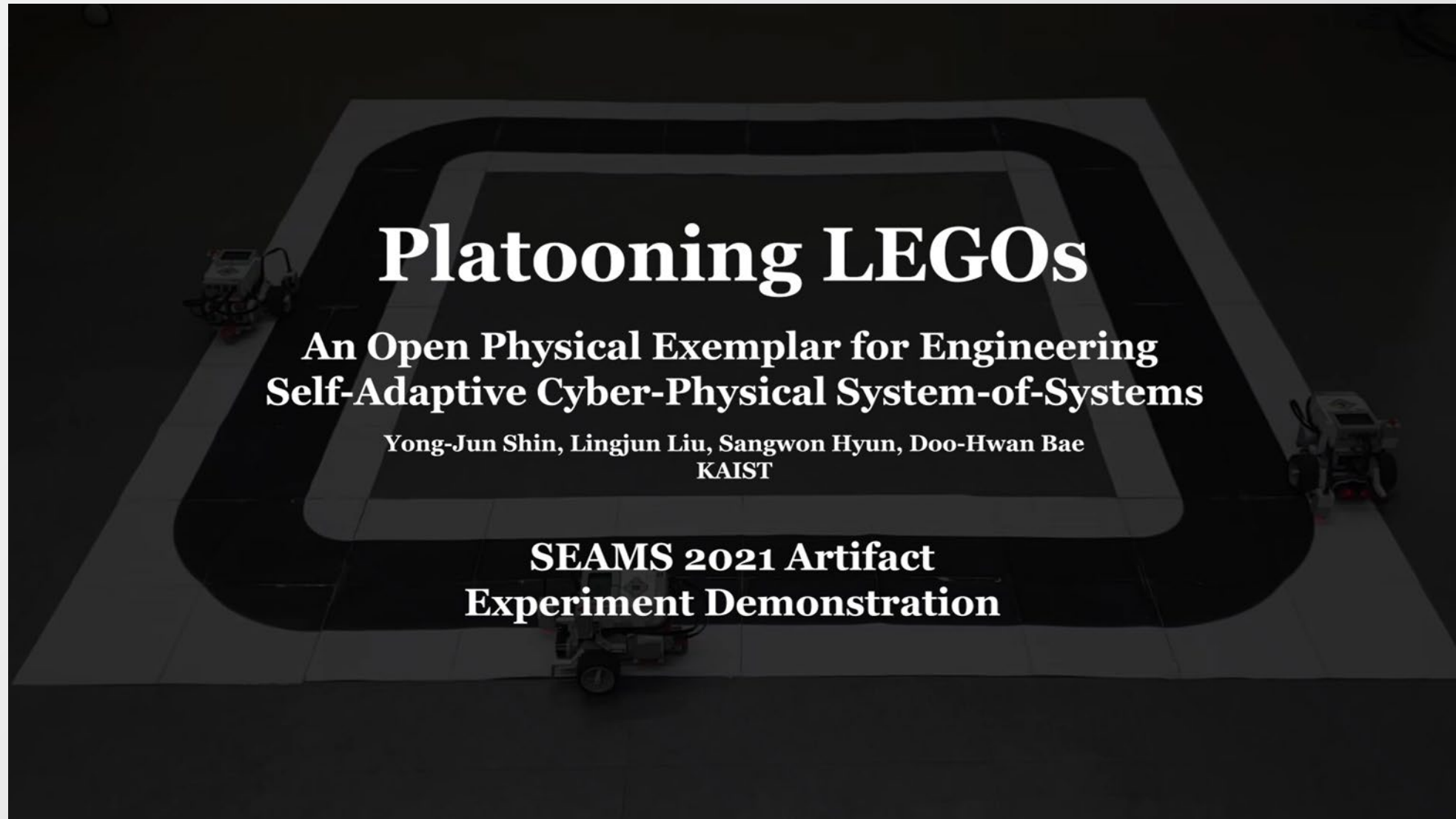• Driving speed
– mm/s
• Turning ratio
– deg/s

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* **A building manual:** https://github.com/yongjunshin/Platooning-LEGOs

LEGOlization : an Infinite Two-lane Highway

20cm

20cm

Inner lane

Outer lane

A4 size

* A building manual:
https://github.com/yongjunshin/Platooning-LEGOs

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Sample Experiment of *Platooning LEGOs*

Contributions

- ◉ **We provided a reproducible physical experimental environment of an industrial vehicular CPSoS for SEAMS community.**
  - Physical experimental design can be shared consistently.
  - It allows field operational experiment using physical sensors and actuators.
  - It makes easy to collect real data.
  - It allows to analyze adaptation logics under test based on the real data.
  - It is easy to build, without mechanic expert knowledge.
  - Building cost is bounded and cheap.

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Thank You.

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