



# CPS: Small: Cyber-Physical Phases of Mixed Traffic with Modular & Autonomous Vehicles: Dynamics, Impacts and Management



2021 NSF Cyber-Physical Systems Principal Investigators' Meeting

Xiaopeng Li (PI), Handong Yao (Post-doc Researcher), Xiaowei Shi (Ph.D. Candidate) Qianwen Li (Ph.D. Candidate), Peng Zhang (Ph.D. Student)

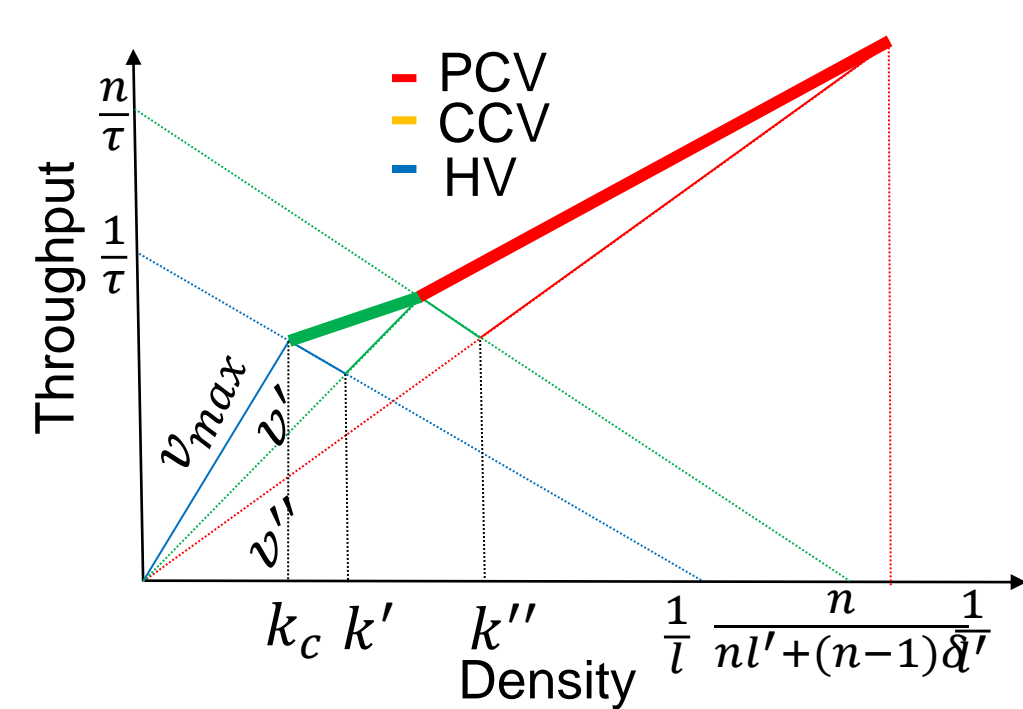
June 2-4, 2021 Award ID#: 1932452

## Objectives

- (1) Advancing knowledge on emerging phases of near-future highway traffic containing cyber-physically connected vehicles.
- (2) Devising management measures for emerging multi-phase mixed traffic to achieve its best performance.
- (3) Validating the key components of the proposed system via a multi-scale autonomous vehicle platform.

## Performance Upper Bound Theory

New triangular fundamental diagram

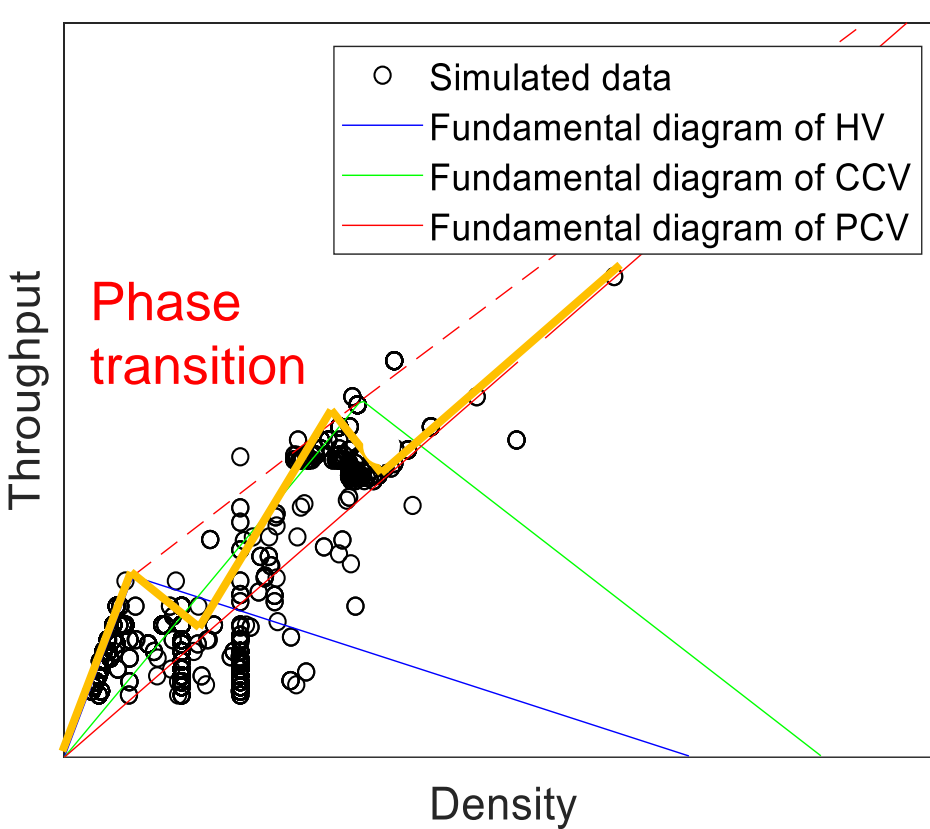


- The highlighted concave upper envelope denotes the ideal upper-bound throughput of mixed traffic (containing HVs, CCVs and PCVs).

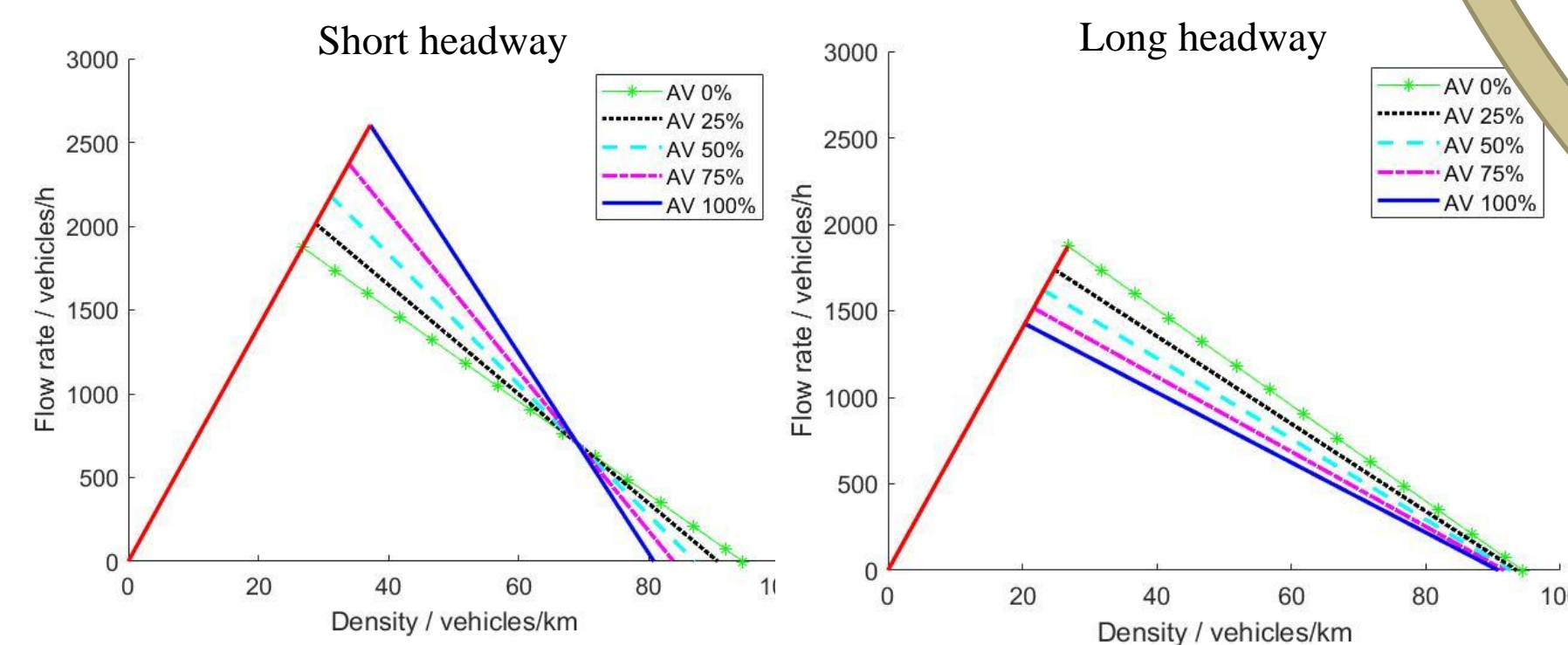
## System Compromise

### Single-lane scenario

- The simulated trend has a smaller magnitude due to physical constraints.



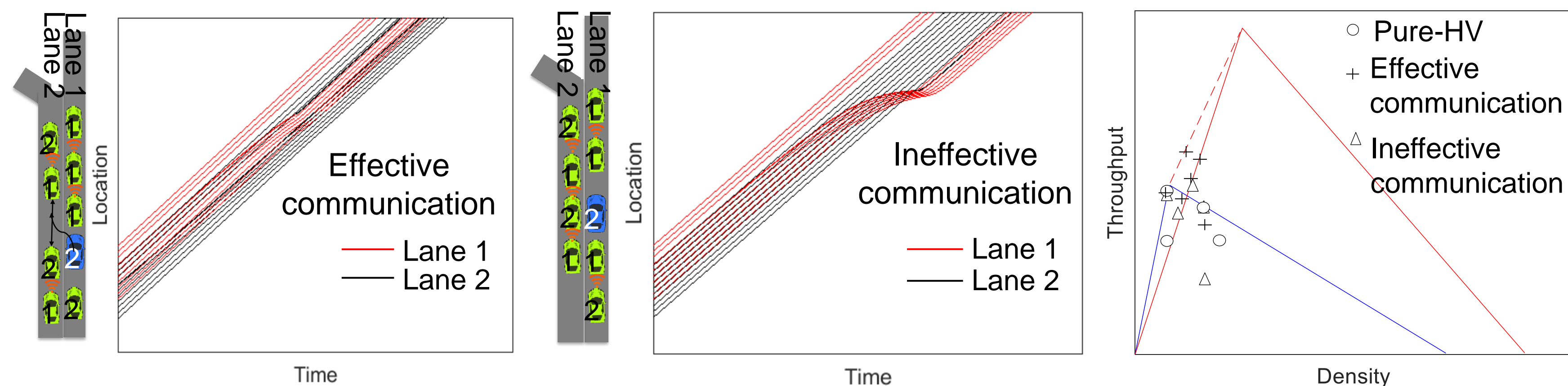
- Mixed traffic fundamental diagram based on field data.
  - A short headway improves the mixed traffic flow road capacity.
  - A long headway causes a lower road capacity than the HV traffic (AV 0%).



[1] Shi, X., & Li, X. (2020) Constructing Fundamental Diagram for Traffic Flow with Automated Vehicles: Methodology and Demonstration. ResearchGate. Preprint.

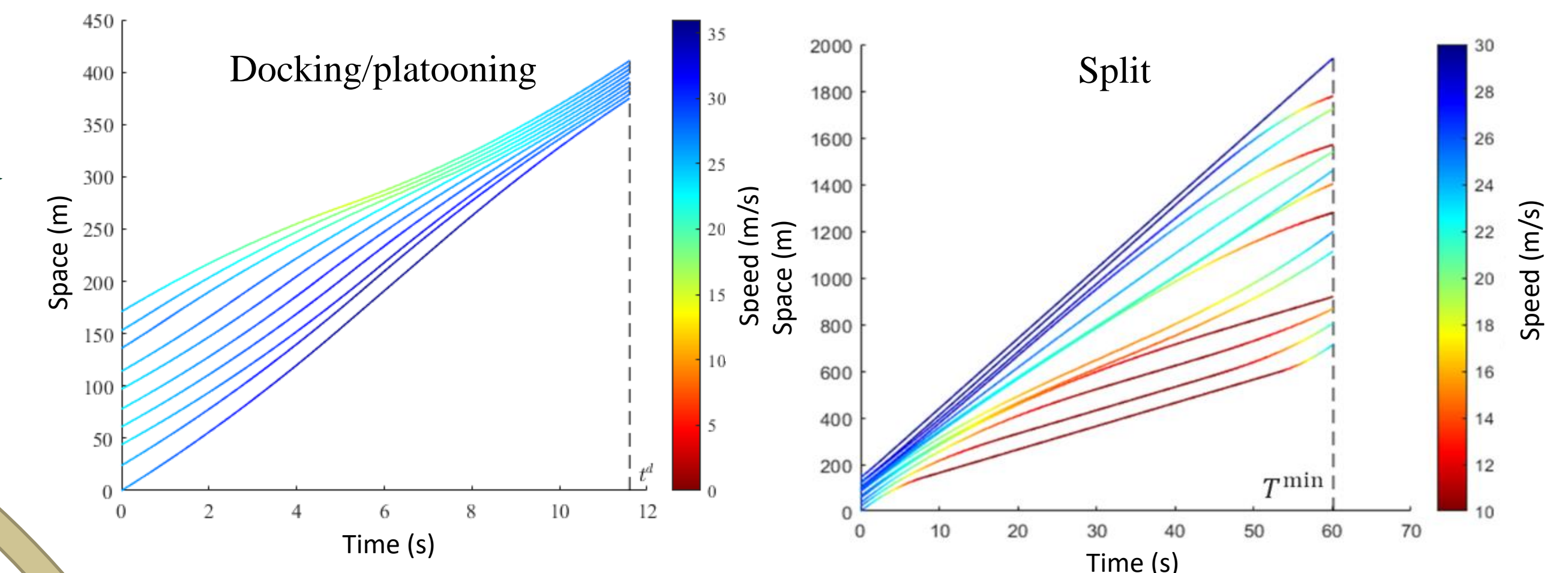
### Multi-lane scenario

- Communication barriers will much reduce the benefits from cyber-connected platoon.



- Operation algorithms (docking/platooning and split) have been proposed for CCVs and PCVs

## Compensation Management Measures



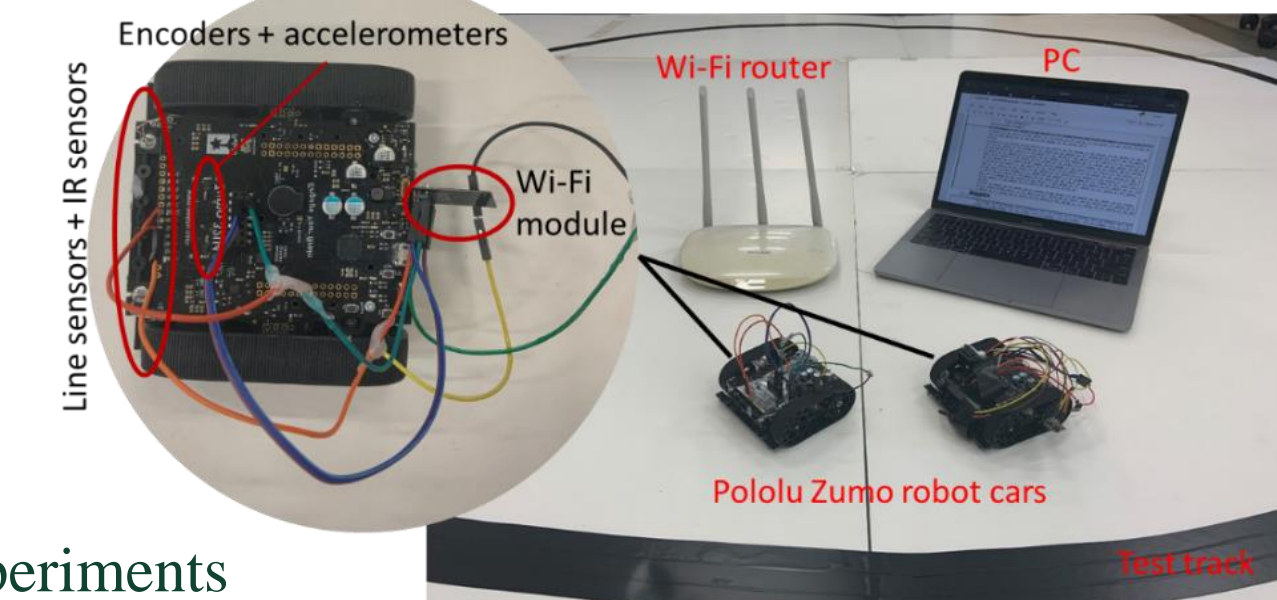
[2] Li, Q., & Li, X. (2020) Trajectory Optimization for Autonomous Modular Vehicle or Platooned Autonomous Vehicle Split Operations. ResearchGate. Preprint.

[3] Li, Q., & Li, X. (2020). Trajectory planning for autonomous modular vehicle docking operations. ResearchGate. Preprint.

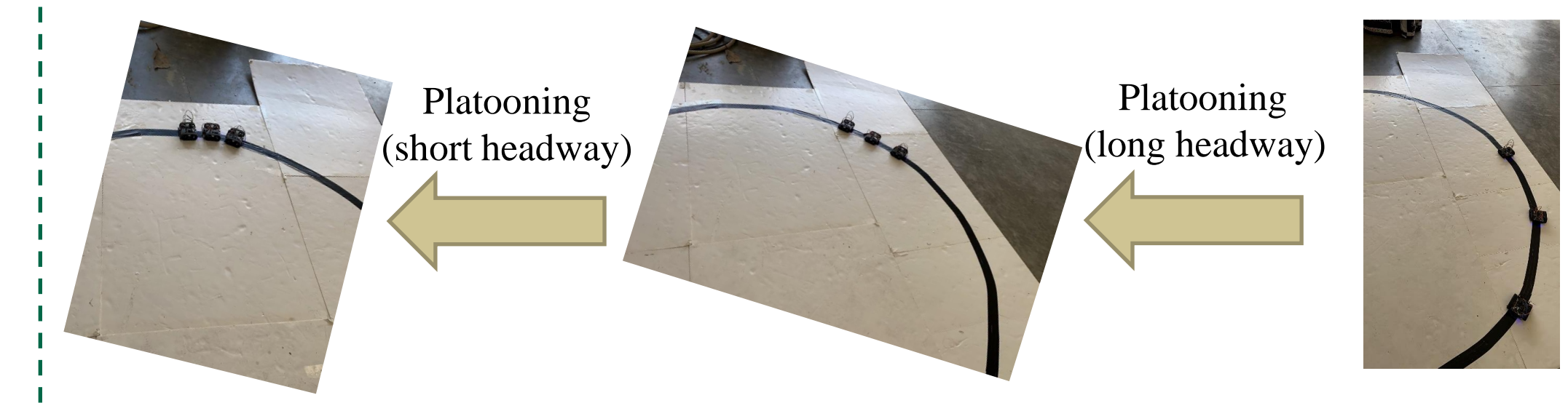
## Evaluation/Experimentation Plan

- Evaluate the performance of the operations of HVs, CCVs, and PCVs considering realistic cyber-physical constraints.

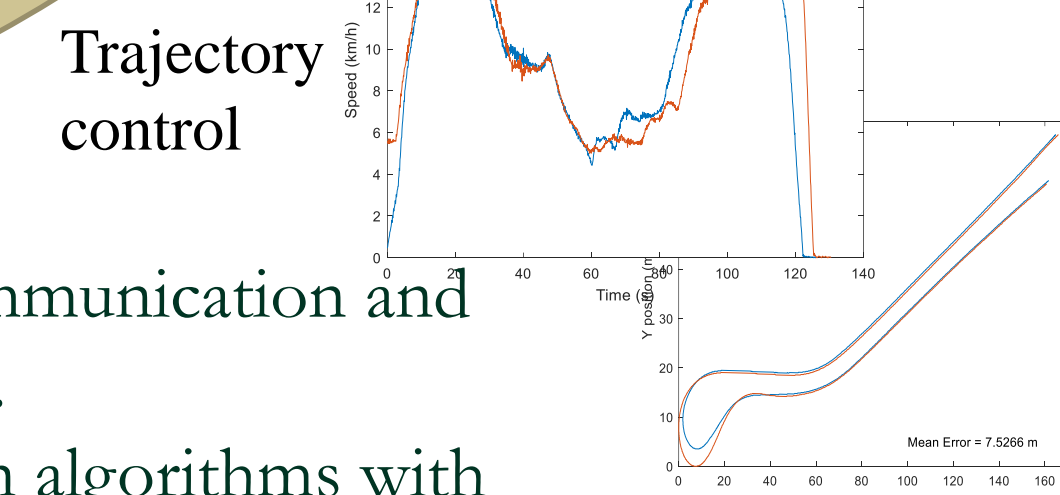
### Scaled robot car tested



- Illustration of small-scale experiments



### V2X communication



### Full-scale CAV testbed



- Test the V2X communication and trajectory control.
- Test the operation algorithms with virtual vehicles generated in simulators.

## Broader Impact

1. Collaboration with **industry partners** will help boost future technology transfers on advance vehicle technologies and management measures.
2. The results will help numerous **transportation stakeholders** understand feasibility and benefits of studying new cyber-physical phases in traffic to incorporate it in their future planning.
3. With multi-scale AV platform, various **education and outreach materials** will be created and applied to teaching K-12 and university students including underrepresented groups.

