FORD OTOSAN

Ford F-Max Platooning Project

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05.10.2020

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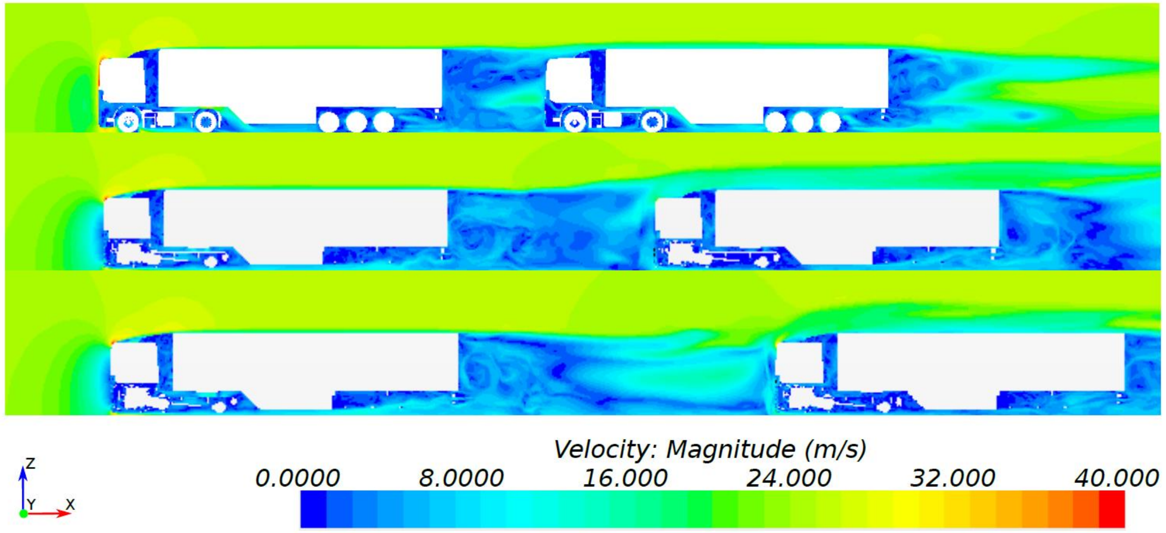
WHAT IS PLATOONING?



CFD results for a platoon of two HDVs with varying inter-vehicle spacing[2]

Safe → Automatic & Immediate Braking

Efficient → Up to %10 Fuel Economy Benefit[1]

Clean → Reduce CO_2 Emissions

Platooning Holds Great Potential To Make Road Transport Safer, Cleaner And More Efficient In The Near Future

ABOUT FORD OTOSAN PLATOONING PROJECT

Aim of the Project:

- SAE-Level 2 Automated Truck Platooning Technology

- With **SAE-L2 Automated Truck Platooning**, trucks will be able to handle platooning management of forming, **merging**, **dissolving**, on top of **distance control** and **lane centering** under the supervision of driver.

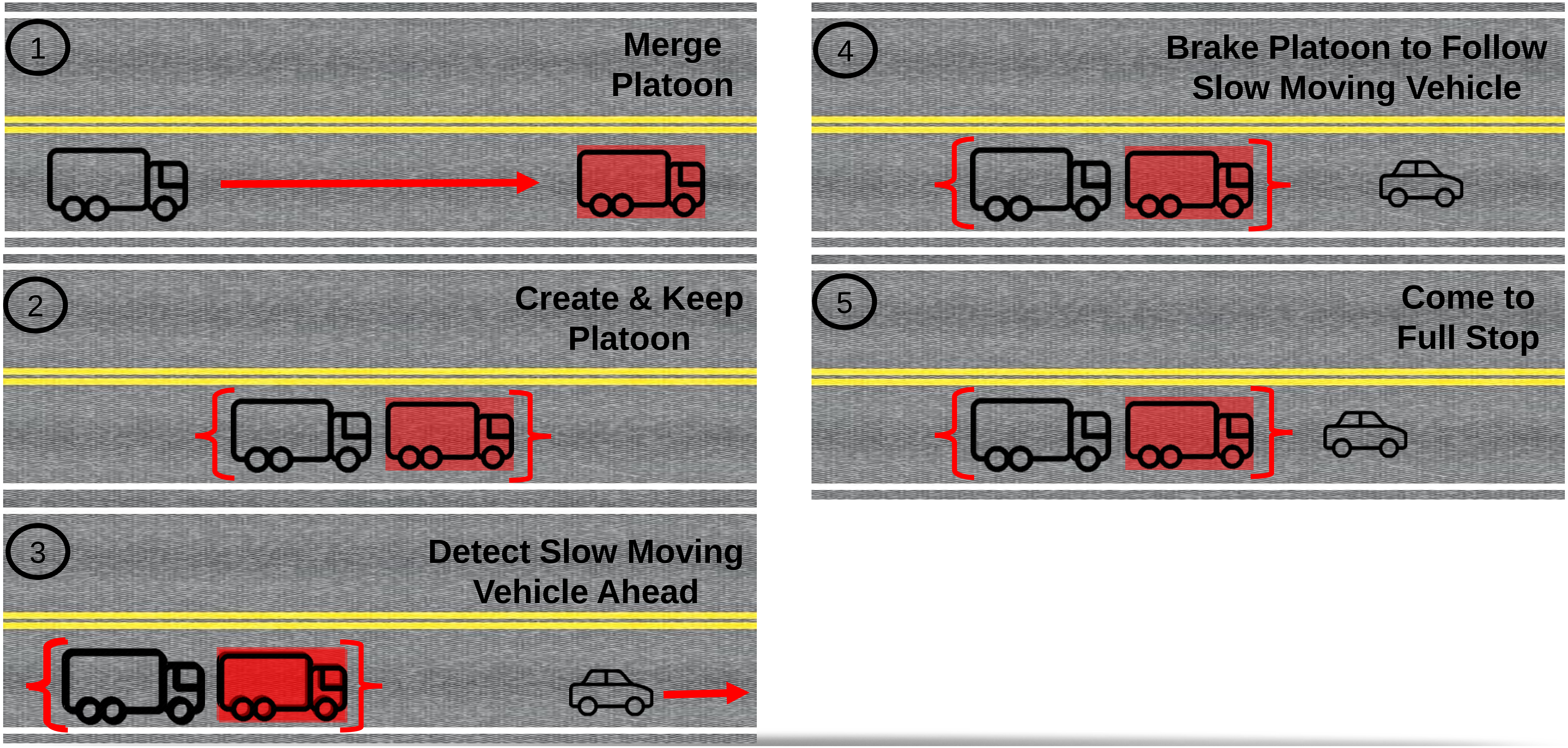
SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability (*Driving Modes*)
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

ERTRAC
European Road Transport Research Advisory Council

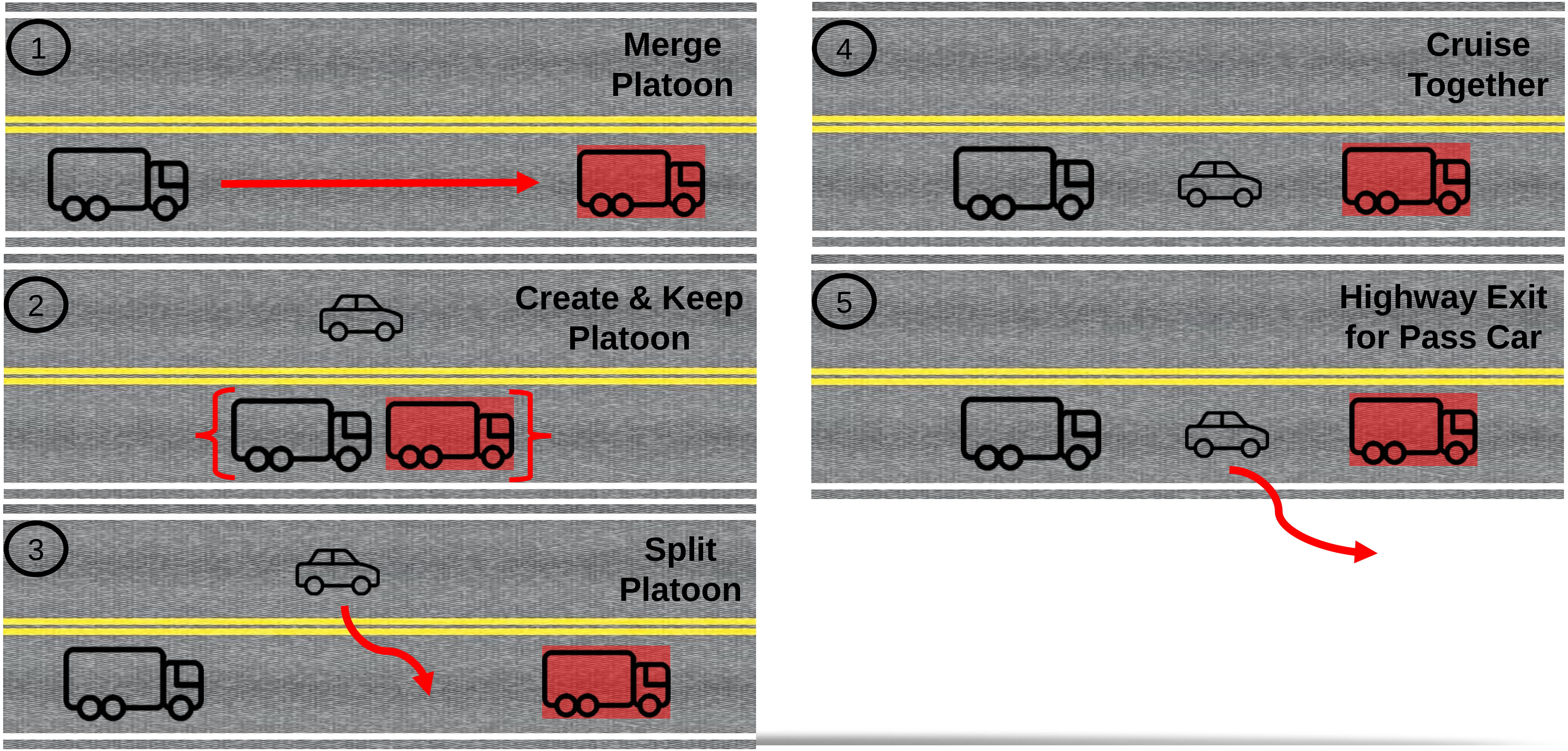
ERTRAC Automated Freight Vehicles Roadmap

- ERTRAC Roadmap suggests implementation start in 2020 with C-ACC [3]
- Platooning requires change of current road regulations (20+)

PLATOONING SCENARIO-1



PLATOONING SCENARIO-2



PLATOONING DEVELOPMENT PHASES

FORD OTOSAN
HEAVY COMMERCIAL VEHICLE

PLATOONING SYTEM
REQUIREMENTS SPECIFICATION

Requirements

Software

Model in the Loop

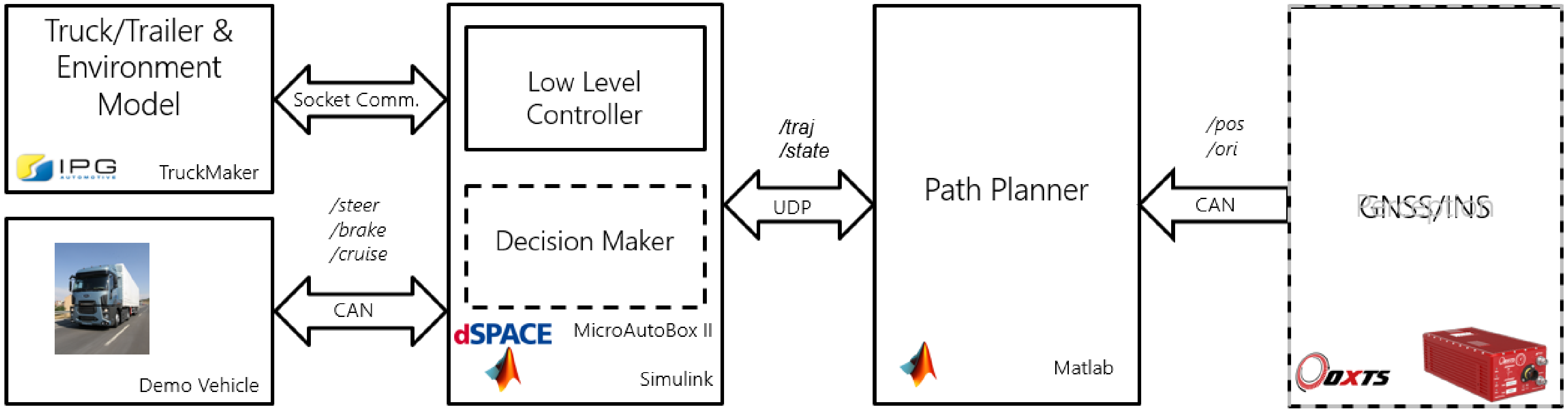
Software in the Loop

Hardware

Hardware in the Loop

Test & Validations
ViL

OVERALL SIMULATION BLOCK DIAGRAM



- Initial Virtual Validations/Simulations for longitudinal and lateral control algorithms are performed using IPG/TruckMaker for Platooning project:

- **High level longitudinal controller** (Distance control between vehicles)
- **Low level longitudinal controller** (Acceleration demand / torque convertor)
- **Lateral control** (Steering angle control of Bosch Servotwin EHPAS steering support)

- Vehicle dynamics model of trucks are corrolated with our F – Max truck in TruckMaker.

CONTROLLER APPROACHES

Platooning Control Problem

Decentralized controllers maintain a desired intervehicular spacing in a vehicle string in the presence of uncertainties and disturbances and use various available feedforward/feedback information.

Difficulty: To ensure that the spacing errors (deviation from the desired intervehicular spacing) do not amplify from vehicle to vehicle along the platoon

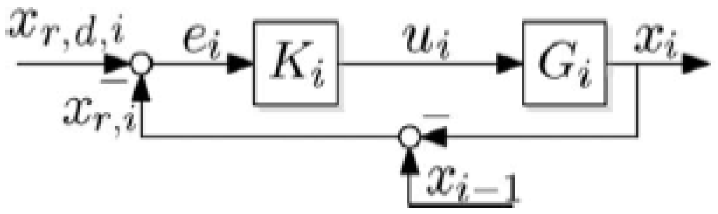
String Stability: It is required to ensure that the spacing errors do not amplify upstream from vehicle to vehicle in a platoon. [5]

Spacing Policies

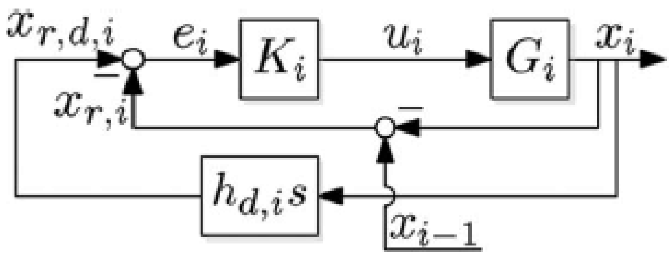
- Constant separation (spacing) (constant)
- Constant headway time (linear)
- Constant safety factor (quadratic)

Conditions

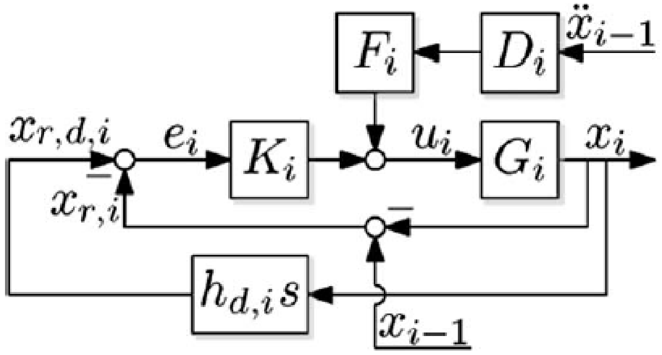
- Individual Vehicle Stability
- String Stability
- Zero steady state spacing error



ACC with constant spacing[4]



ACC with constant headway time[4]

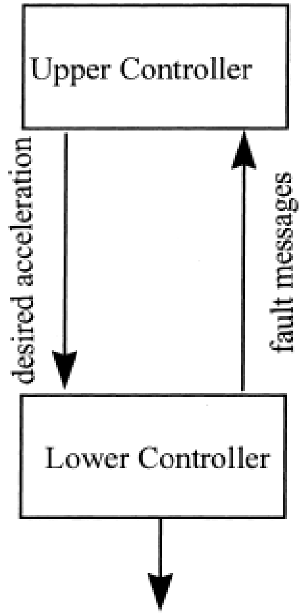


CACC[4]

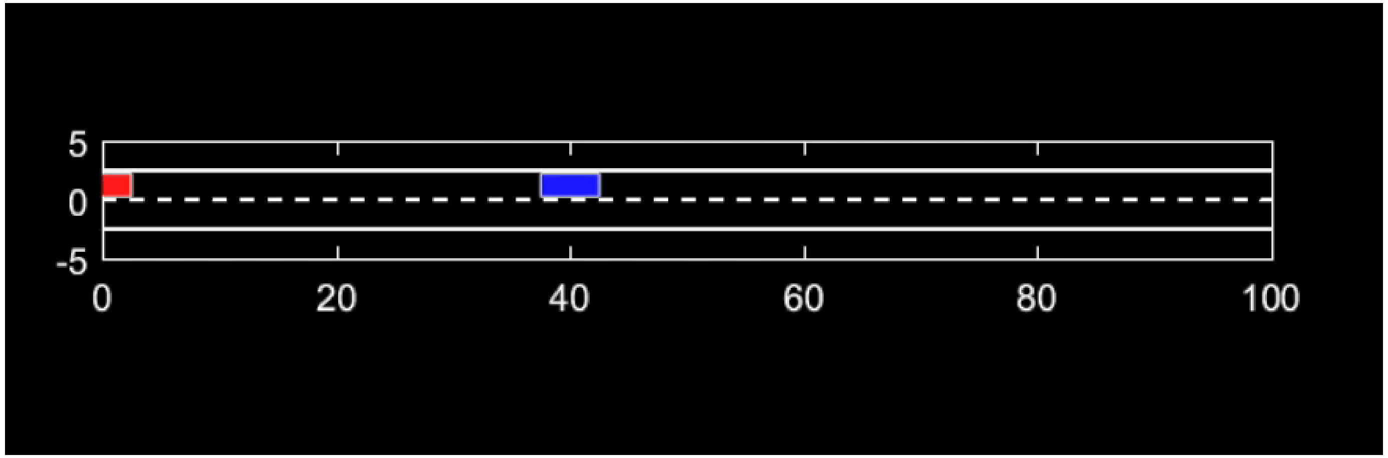
VALIDATIONS OF CONTROLLER APPROACHES

- Variety of controllers are tested in SIL and MIL environment to have more testing oppurtunity at field to avoid nonlinearities or uncertanties of prototype vehicle.
- First implementations of the algorithms are done in MATLAB/Simulink Environment.
- Model-in-the-loop testings and validations are done in TruckMaker Simulink Environment.
- Further simulation studies like 3 or more trucks included TruckMaker SimNet Add – On can be used.

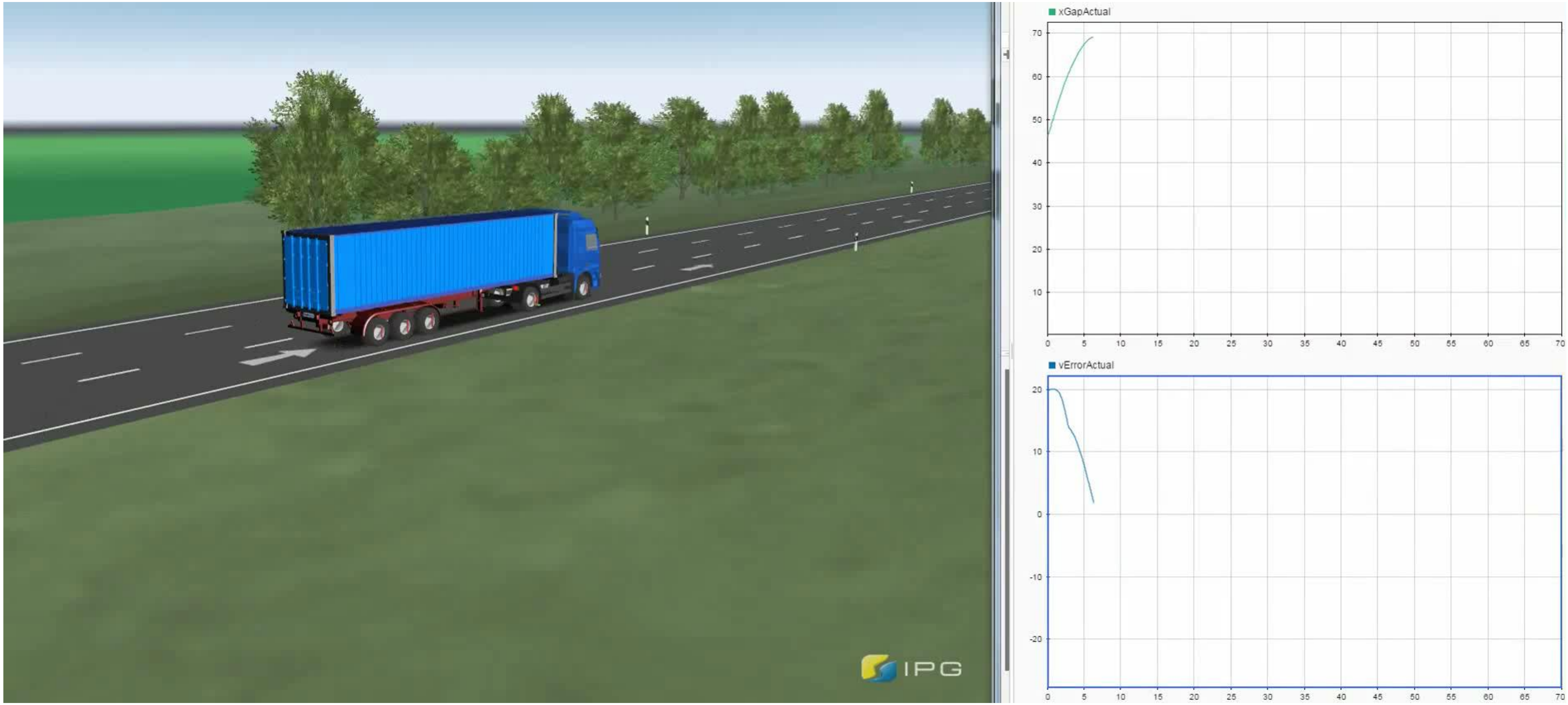
- **The lower level controller** determines the throttle and/or brake commands required to track the desired acceleration.
- **The upper (higher) level controller** determines the desired acceleration for each vehicle.



An example of MATLAB/Simulink testing results



IMPLEMENTATION WITH TRUCKMAKER



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- [1] F. Browand, J. McArthur, and C. Radovich. Fuel saving achieved in the field test of two tandem trucks. Technical report, California PATH Research Report, CA,USA, July 2004.
- [2] A. Alam. Fuel-Efficient Distributed Control for Heavy Duty Vehicle Platooning. PhD thesis, KTH, Sweden, 2011.
- [3] ERTRAC-CAD-Roadmap-2019
- [4] Naus, G. J., Vugts, R. P., Ploeg, J., Marinus J G Van De Molengraft, & Steinbuch, M. (2010). String-Stable CACC Design and Experimental Validation: A Frequency-Domain Approach. *IEEE Transactions on Vehicular Technology, 59*(9), 4268-4279. doi:10.1109/tvt.2010.2076320
- [5] Swaroop, D., 1995, “String Stability of Interconnected Systems: An Application to Platooning in Automated Highway Systems”, *Ph.D. Dissertation*, University of California, Berkeley, 1995.

CONTACT INFORMATION

Thank you for listening

- If you have any further quenstions do not hesitate to contact :

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