Connected and Automated Trucks: What and When?

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Overview

- **Automation 101 – terminology and classifications**
- **PATH background on connected and automated trucks**
- **Truck platooning – what it is and why it's important**
- **Levels of truck automation and when they may happen**

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Automation Terminology Problems

- **Common misleading, vague to wrong terms:**
  - **“driverless” – but generally they’re not!**
  - **“self-driving”**
  - **“autonomous” – 4 common usages, all different in meaning (and 3 are wrong!)**
- **Central issues to clarify:**
  - **Roles of driver and “the system”– levels of automation**
  - **Degree of connectedness and cooperation – V2V, I2V, V2I**
  - **Operational design domain**

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Levels of Automation - Classifications

Driving automation systems **are categorized into levels based on:**

1. **Whether the driving automation system performs *either* longitudinal *or* lateral vehicle motion control.**
2. **Whether the driving automation system performs *both* longitudinal and lateral vehicle motion control simultaneously.**
3. **Whether the driving automation system *also* performs object and event detection and response.**
4. **Whether the driving automation system *also* performs fallback (fault recovery).**
5. **Whether the driving automation system can drive everywhere or is limited by an operational design domain (ODD).**

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Operational Design Domain (ODD)

- **The specific conditions under which a given driving automation system is designed to function, including:**
  - **Roadway type**
  - **Traffic conditions and speed range**
  - **Geographic location (boundaries)**
  - **Weather and lighting conditions**
  - **Availability of necessary supporting infrastructure features**
  - **Condition of pavement markings and signage**
  - **(and potentially more…)**

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Example Systems at Each Automation Level

(based on SAE J3016 - http://standards.sae.org/j3016_201609/)

Level	Example Systems	Driver Roles
1	Adaptive Cruise Control OR Lane Keeping Assistance	Must drive other function and monitor driving environment
2	Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist (Mercedes, Tesla, Infiniti, Volvo…) Parking with external supervision	Must monitor driving environment (system nags driver to try to ensure it)
3	Traffic Jam Pilot	May read a book, text, or web surf, but be prepared to intervene when needed
4	Highway driving pilot Closed campus “driverless” shuttle “Driverless” valet parking in garage	May sleep, and system can revert to minimum risk condition if needed
5	Ubiquitous automated taxi Ubiquitous car-share repositioning	Can operate anywhere with no drivers needed

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Early PATH Research on CAV Trucks

Automatic steering control – 1998-2000

Two-truck platoon control – 2003

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Why care about truck platooning?

- **Significant energy savings from aerodynamic drafting**
- **More stable vehicle following dynamics, reducing traffic flow disturbances and saving additional energy and emissions**
- **Increased highway capacity and reduced congestion from improved traffic dynamics and shorter gaps**
- ***(Potential)* safety improvement**
- ***(When Level 3 automation becomes feasible)* Improvement in truck driving working conditions, with more diverse assignments for drivers on the road**
- ***(When Level 4 automation of follower trucks becomes feasible)* Reduced need for truck drivers on line haul**

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Enablers of Truck Platooning

- Adaptive cruise control (forward ranging sensor, plus engine, braking and transmission control) already available
- Fast, highly reliable V2V communication
- Informative driver-vehicle interface
- Reliable early detection of cut-in vehicles
- (For L2+) Lane position detection and automatic steering control
- (For L3+) Central supervision, I2V comm.
- (For L4) Extensive safety assurance + dedicated, segregated truck lanes (?)

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L1 Truck Platooning State of the Art

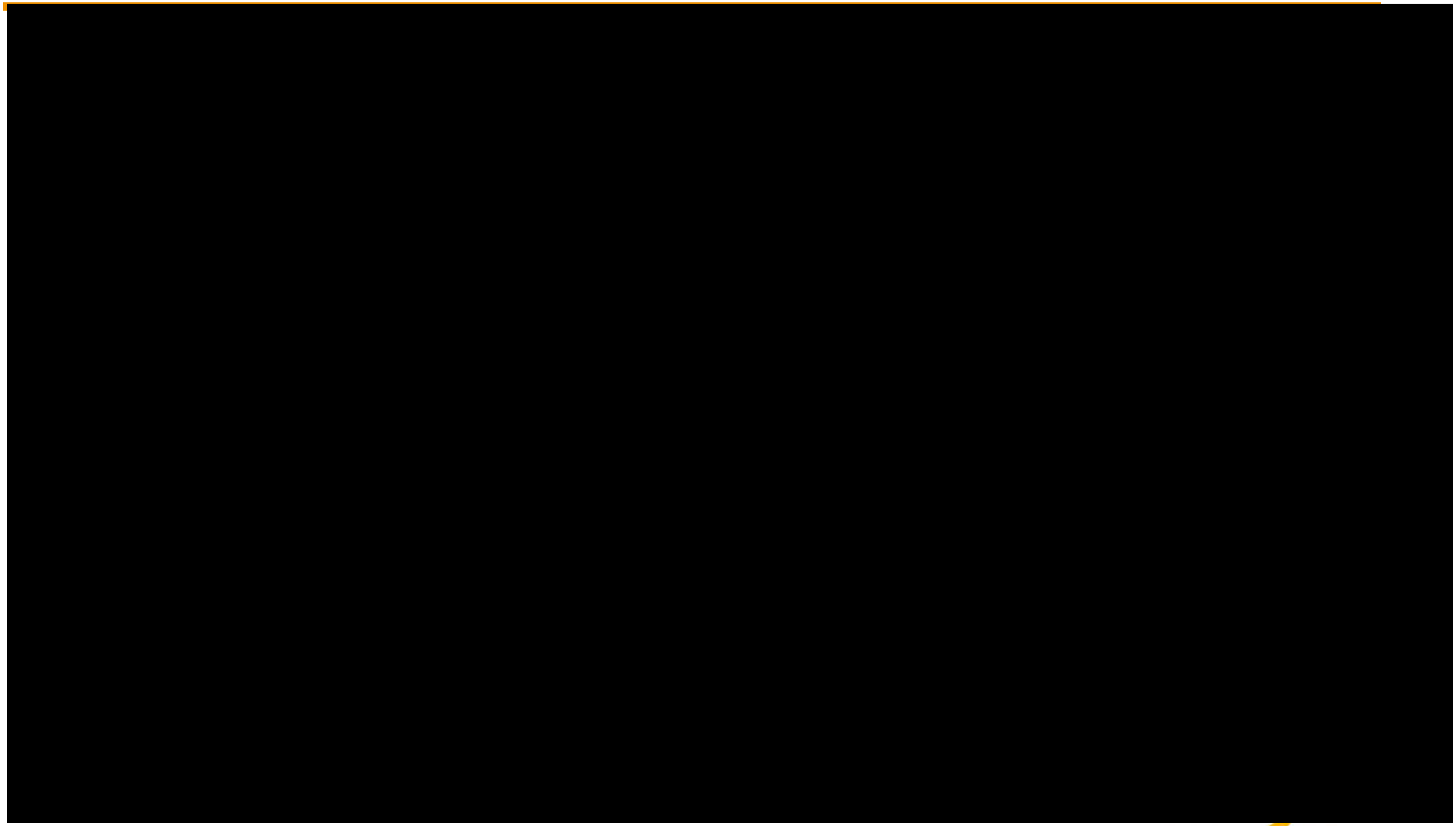
Automated longitudinal control only

- **Cooperative ACC as first step (pre-platoon)**
  - **V2V communication/coordination**
  - **Ad-hoc joining and leaving**
  - **Constant time-gap following**
- **L1 Platooning**
  - **Add coordination/supervision by leader**
  - **Extend to constant clearance distance gap and shorter distances**
- **Many research and development projects**
- **Peloton Technology planning 2-truck product release**
- **Major truck manufacturers considering it seriously, but no announcements yet**

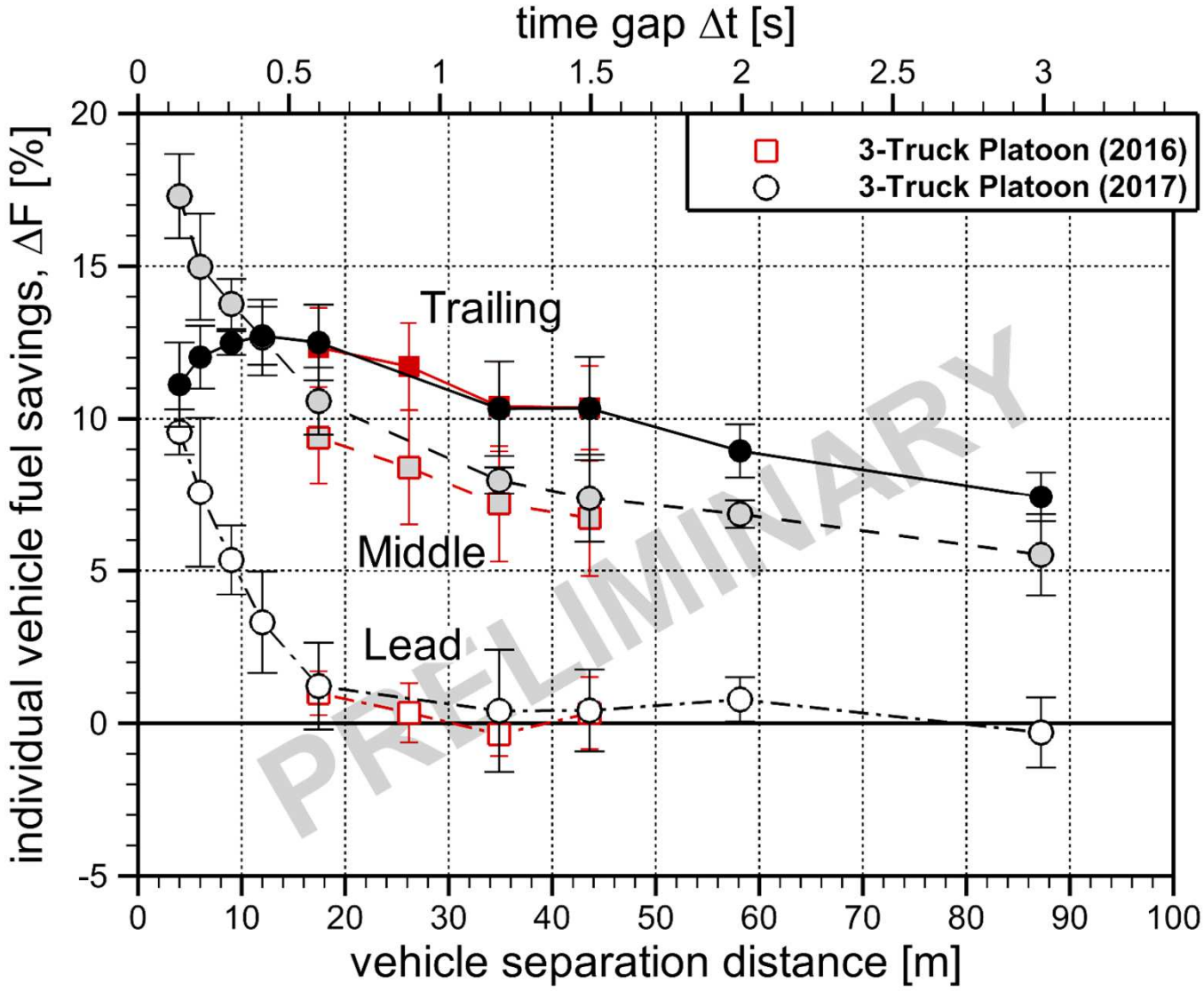
PATH/Volvo Truck CACC at 0.6 s Gap on Transport Canada's Test Track (10/16)

PATH/Volvo Truck Platoon at 4 m Gap on Transport Canada's Test Track (8/17)

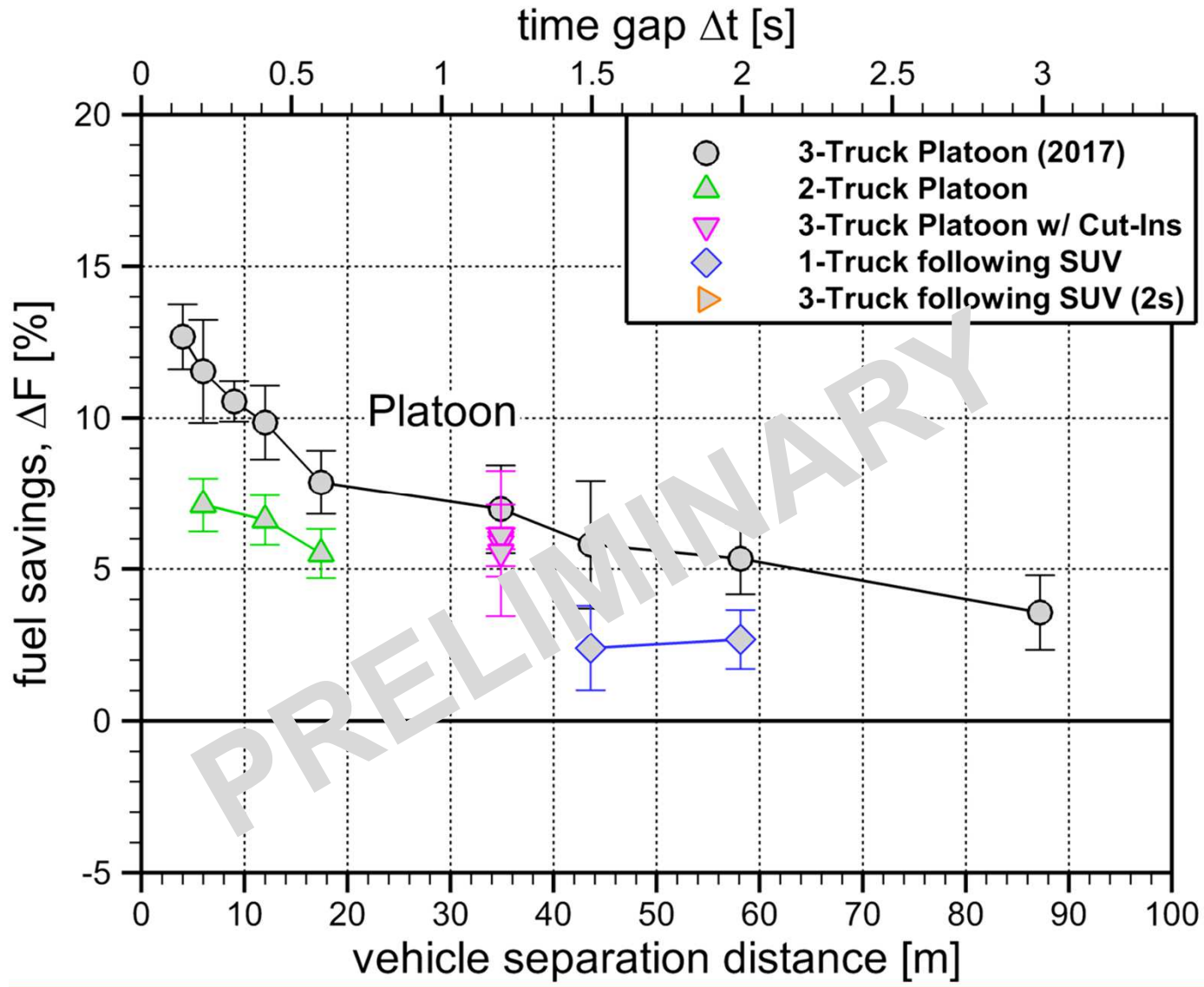
PATH/Volvo Truck CACC, Including Response to Cut-in Vehicle



Fuel Savings per Truck at 110 km/h (65 mph)

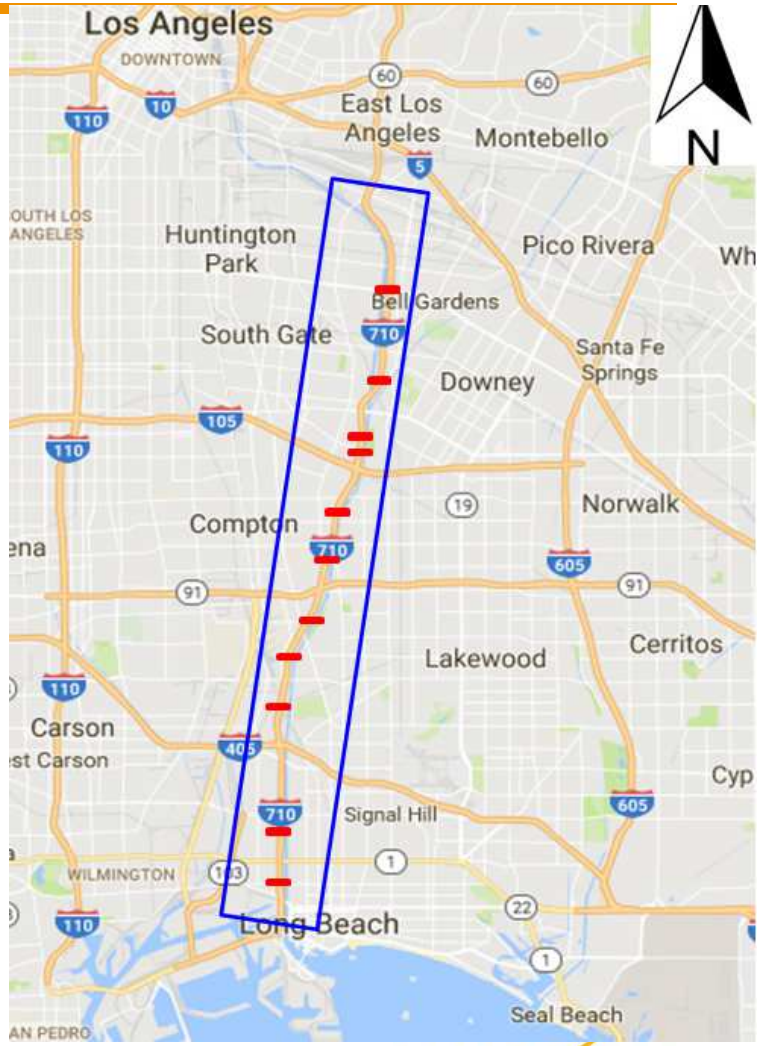


Fuel Savings for Complete Platoon (Average) at 110 km/h (65 mph)



Traffic Impact Study for I-710 Corridor

- **15 miles, 21 on-ramps, 20 off-ramps**
- **10% - 19% truck volume**
- **Morning off-peak (10-11 am) simulated northbound**
- **If all trucks can use CACC for close following:**
  - **Truck average speed +19%**
  - **Truck flows +2% -- +8%**
  - **LDV traffic unaffected**
  - **Trucks save ~2.5% of fuel (2% from traffic flow, 0.5% from aerodynamics)**



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L2 Truck Platooning State of the Art

L1 platooning + automatic steering control

- **Automatic steering likely necessary for shorter longitudinal gaps (visibility limitations)**

- **Multiple research projects have tested it, from CHAUFFEUR (1996-2004) to Konvoi, SARTRE, Energy ITS, etc.**
- **Some companies doing R&D on it (Daimler, Scania, Uber ATG, Waymo,…)**
- **Product releases?? Within a few years**

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L3 Truck Platooning State of the Art

L2 + driver can divert attention *temporarily* to other tasks, while remaining available to intervene when needed

- **Follower truck driver could work as sales person or logistics manager *en route***

- **Research needed on driver-vehicle interface to try to ensure driver availability when needed**
- **Remote supervision (by lead driver over V2V or central supervisor over I2V link) could be needed**
- **Passenger car applications likely to precede heavy trucks**
- **Product releases? ~5 years?**

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L4 Truck Platooning State of the Art

L3 + ability to ensure minimal risk condition without any human intervention (while operating within its specified Operational Design Domain – ODD)

- **L4 platoon followers likely to be coupled behind a leader driven at L0, L1 or L2.**
- **Singapore requesting this now for a 10 km route connecting two container terminals**
- **Safety assurance state of the art not sufficient to support this level of automation for mixed traffic and highway-speed operations**
- **Likely to need segregated truck-only lanes or other special restrictions to simplify the ODD – like current port and mine applications**

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Potential Loss of Truck Driver Jobs?

- **Starting from current shortage of drivers and aging driver population**
- **Any current truck driver will be able to retire, not go on unemployment**
- **Elimination of driver roles will take decades:**
  - **Safety assurance en route**
  - **Condition monitoring**
  - **Loading and unloading, load securement**
  - **Interfaces with shippers and receivers (pickup and delivery)**
  - **Managing the unexpected**
- **Add fleet turnover time**

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