Platooning using 802.11p
…in SARTRE project
Safe Road Train for the Environment

SARTRE
Safe Road Trains for the Environment

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Road Trains – a concept for the future

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Available on you tube.

Presentation outline

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- SARTRE platooning concept and project setup
- Technologies used
- Testing and results
  - Public road testing
  - Fuel consumption tests
  - v2v tests
- Conclusion

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SARTRE Project

- A public funding European project run 3 years, starting autumn 2009 (end 2012)
- Participation from 7 partners from 4 countries:
  - Volvo Trucks, Volvo Cars and SP (Sweden), Ricardo (UK), IKA (Germany), IDIADA and Technalia (Spain).
- SARTRE have developed a platoon lead by a commercial vehicle (Volvo Truck) and follow by another Volvo Truck and three Volvo passenger cars
- All following vehicles are automatically controlled for both steering and acceleration/braking
- Using already existing automotive technologies combined in a new way
- **Project objectives**
  - Reducing environmental impact
    - by fuel consumption savings
  - reducing congestions
    - by more efficient use of the road network
  - increased safety
    - the road train should be at least as safe as normal driving, and the platoon is lead by a professional driver

Platooning Definitions

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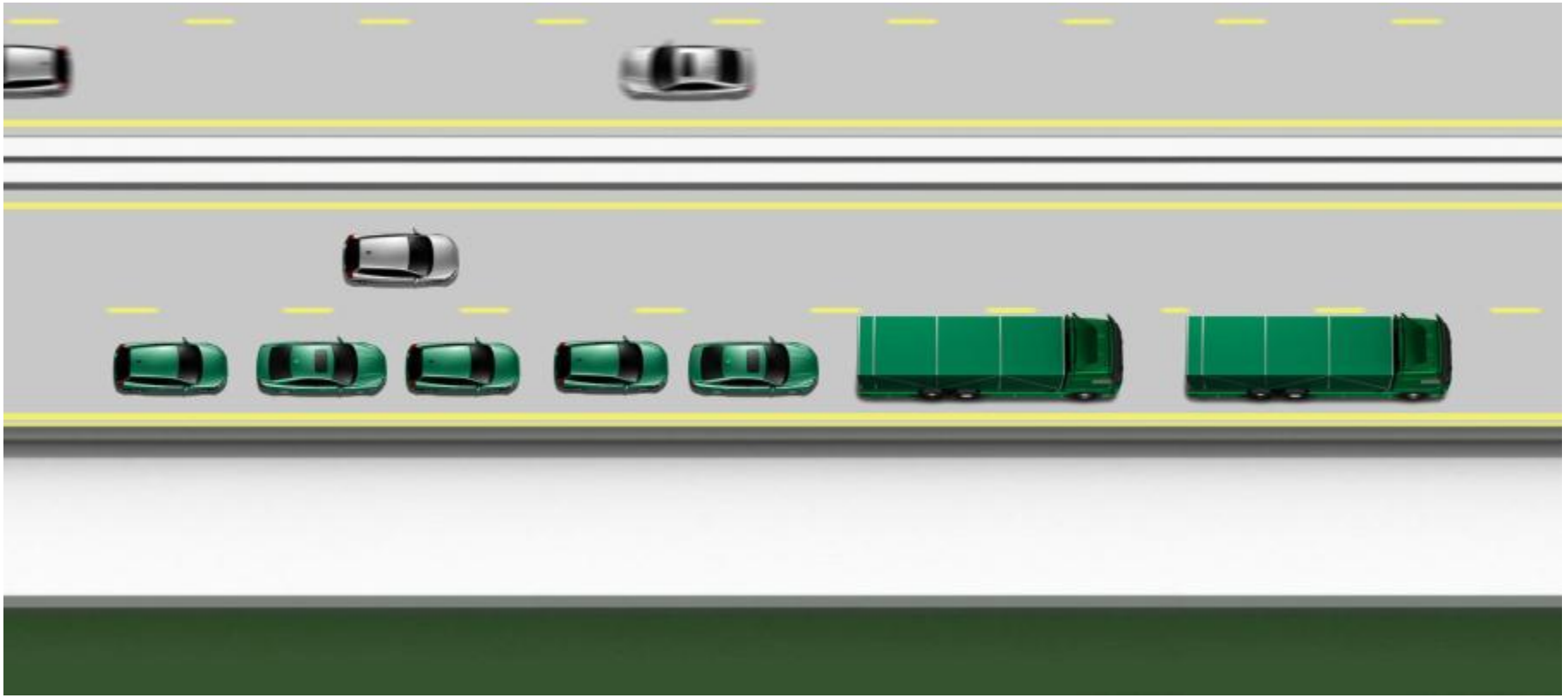

- a *Platoon* is a number of vehicles that are travelling together and electronically connected (e.g. via wireless communication).

How the technology works

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- The first truck is manually driven by a certified lead driver
- An electronic breadcrumb trail is created by the lead truck, communicated by the Wi-Fi link
- All following trucks and cars area following the breadcrumb trail, driving in the *same wheel tracks* as the truck in front
- The spacing between the vehicles is kept automatically at a defined distances, *down to 5m* using a combination of radar and Wi-Fi data to reduce fuel consumption

Technologies used

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- One important project goal was to not to develop using advanced prototype systems but *combining these existing technologies in a new way*
- Steering and Distance keeping
  - Acceleration and braking is already used in the production trucks for radar based adaptive cruise control and automated emergency braking
  - Automated Steering was realized using add-on electric motor
- Radar and Camera technologies
  - Production standard technologies have been used, combined in a clever new way
- Wi-Fi Communication
  - Wi-Fi between the vehicles has been implemented using the automotive standard *802.11p*
- Volvo's already existing systems for driver assistance and driver alert support has been used to support the lead truck driver in his driving task

Technologies in the Trucks

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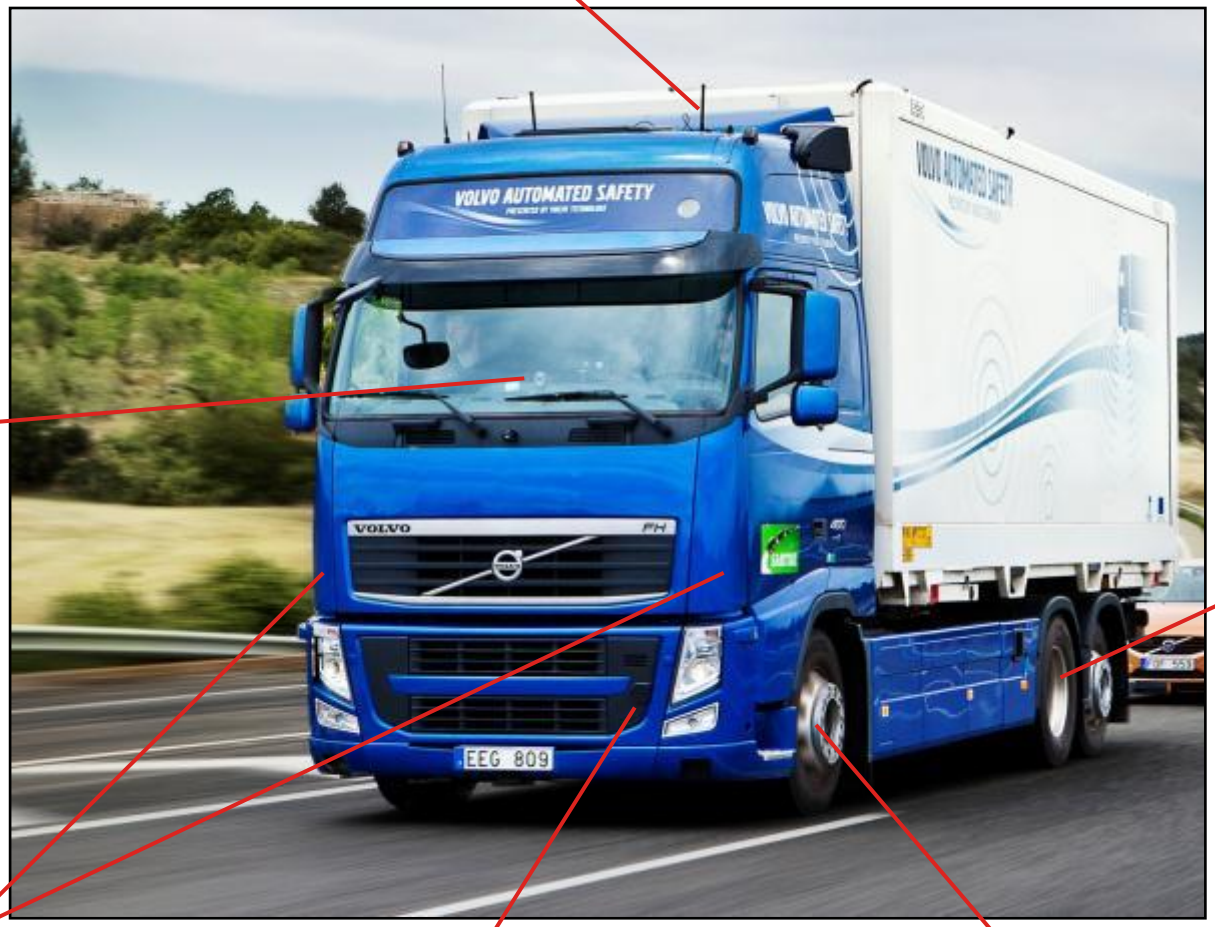
Antenna used for
Wi-Fi communication



Camera
measuring
position in lane

Electronically
controlled
acceleration and
braking

Side Radars to
monitor traffic

Radar for distance
keeping

Electronically
controlled steering

The safe lead driver

- **The lead vehicle should be driven by a professional driver trained for leading other vehicles in a road train.**

- **The lead driver is essential to the platoon both for safety and fuel consumption of the complete system.**
- Driver support systems from production:
  - *Alcolock and Tachometer*
  - *Adaptive cruise control system* (long range radar)
  - *Driver Alert Support (front-looking camera)*
  - *Lane Keeping Support (front-looking camera)*
  - *Lane Change Support (side-looking short range radar)*
- Driver support systems from research programmes:
  - Driver Monitoring system from HAVEit research project

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SARTRE –Video from On Road test day in Spain 22nd May 2012

The video was recorded during the actual test on a public highway, open to other traffic.

Available on youtube at Volvo Trucks channel

Location: Barcelona, Spain - 22 May 2012

SARTRE – Fuel consumption tests

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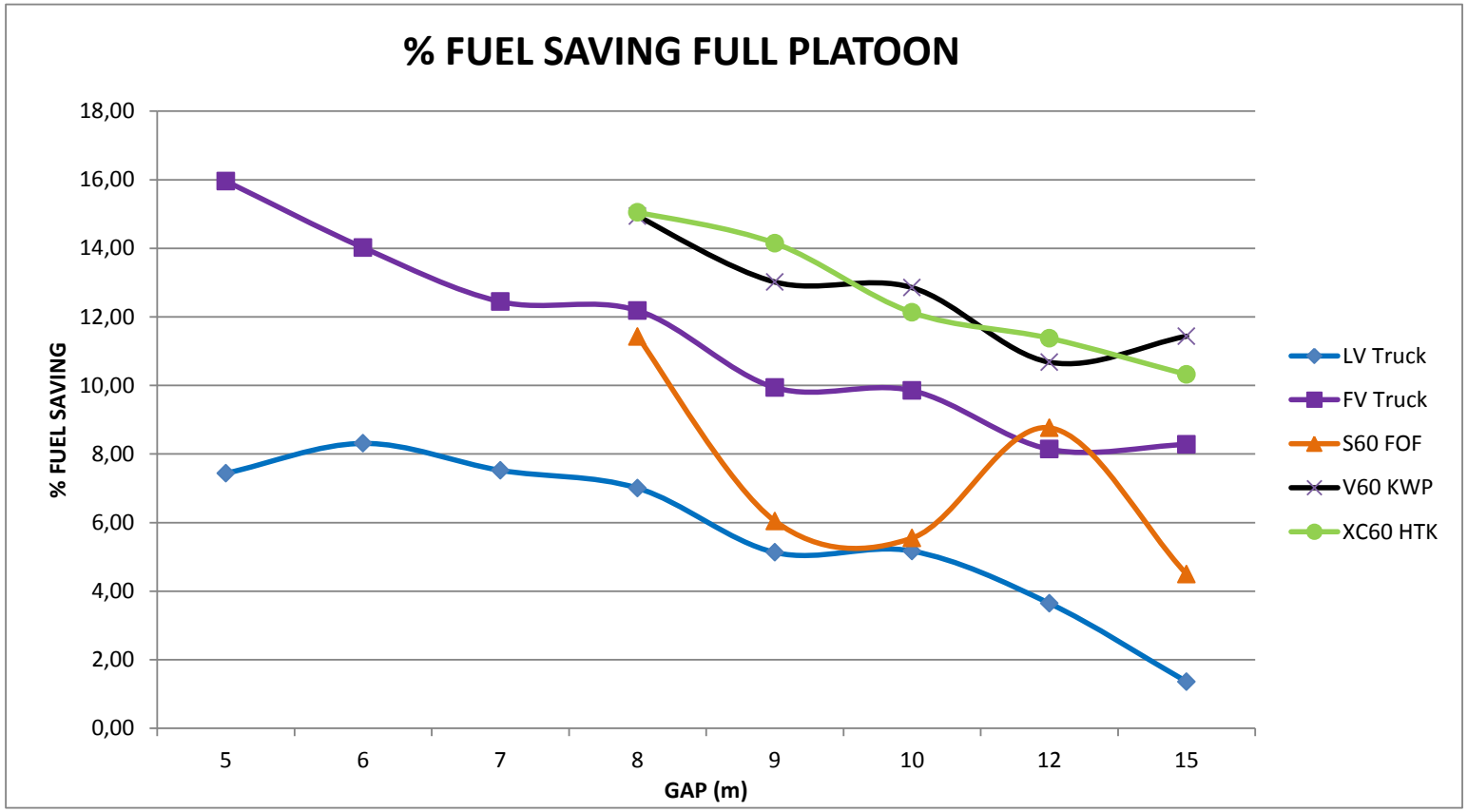
- Simulations of aerodynamic effects on fuel consumption
- Fuel consumption was recorded at the IDIADA high-speed test track South of Barcelona in Spain
- A rather short testing period stressed that the tests were carefully performed and monitored.
- Tests were perfomered a night, to make sure that temperatur and wind aspects were constant

SARTRE – Results from fuel consumption tests

- Data was recorded using in-vehicle signals using EuroFOT project logging equipment to ensure valid data.
- A rather short testing period stressed that the tests were carefully performed and monitored.
- Tests were performed a night, to make sure temperature and wind aspects were constant



SARTRE V2V Communication

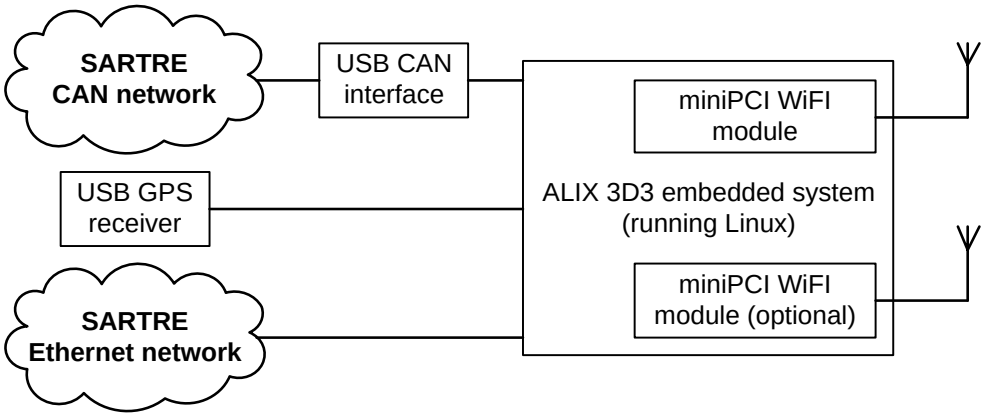
SARTRE V2V communication setup

- Based on 802.11p, G5-control channel, 20dBm Tx-power

..but UDP/IP, not ETSI ITS stack (e.g. CAM, DENM was not used)

- Data is broadcast across all vehicles, no multihop
- Data encryption using a pre-shared key has been tested
- Data is time stamped using GPS and NTP
- Transmission rate is 40Hz (25ms)
- The V2V system was designed to satisfy *possible* control needs
  - The focus has not been to limit the amount of data transmitted and further projects need to work on the actual needs for the control.
- Data was sent and received from the SARTRE CAN bus
  - Control (vehicle parameters for all vehicles)
  - Object information
  - HMI (request to join/leave etc)
  - Platooning status (platoon ID order etc)

V2V communication HW



260mm high
5.9Ghz antenna

Antennas on
Trucks

Tested position but
not used in
platooning demo

Antenna on FV Car

SARTRE V2V test setup

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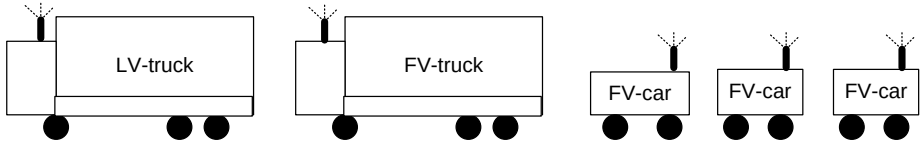
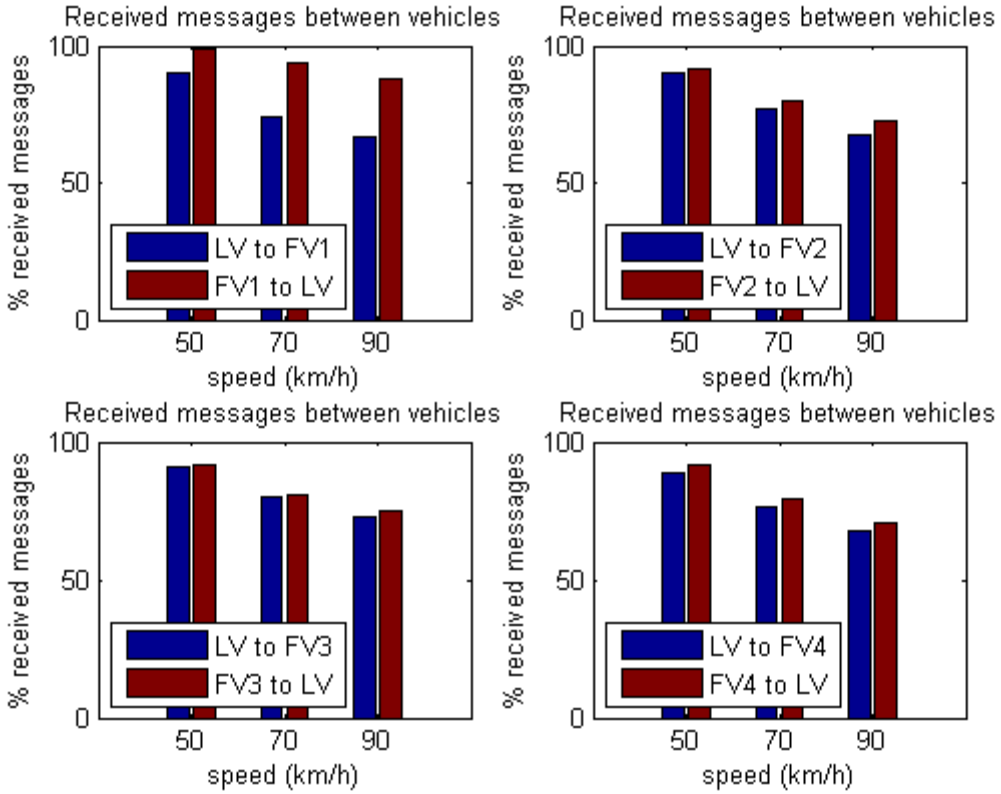
- Tests in April 2012 at the IDIADA test track in Spain
- Two different test tracks.
- Three speeds: 50, 70, 85 km

- Platoon: Two trucks and three cars, distance 13m, manually driven
- Trucks have V2V-nodes with two separate radios each with one antenna
- Cars have V2V-node with one radio / antenna.



V2V test result: Lost messages



- Line of sight problems between the truck and the cars is the possible cause for differences at the closest following vehicles.
- Percent of received messages between LV and FVs when platooning at different speeds. Platooning was undertaken for 6 minutes for each speed at a distance of 13m.
- The final system configuration worked well with the setup of communication.

SARTRE V2V results and experiences

- In the final system v2v worked as expected

- Time synchronisation solutions have been tested , a GPS/NTP solution was implemented in the final system
  - **Time sync is especially important for control applications**

- It is **important to consider communication limitations in the control design**
  - v2x data fused with onboard sensors

- ETSI standardisation was not used:
  - Future projects needs to **consider adaption to (and of) ETSI standard**.

- Data encryption was used, a pre-shared key has been tested:
  - **Safe and secure data exchange important** in this type of control applications

Conclusion

- Automated Driving of Vehicles is happening now!
- Reduced fuel consumption is to be expected using platooning
- The technology is well on the way to platooning
  - most of the technology components are ready.
  - but there are a number of challenges, SARTRE is a proof-of-concept, not a product!

- Legal implications
  - The Vienna convention on Road Traffic
  - European legislation differs from country to country
  - The situation in US differs between the states
- Connected to the legal implications of the Vienna convention there are issues to be raised in the insurance industry.
  - Who is responsible for accident
  - Is the OEM also product liability responsible
- Societal factors
  - The public needs to accept platoons
  - Driver education is needed, as the traffic environment is new with platoons on the road.

Example:
Ongoing related research projects at Volvo

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- FFI collaboration:
  - WCAE (Contact: Magnus Olbäck, Volvo GTT)
  - RelCommmH (Contact: Magnus Olbäck, Volvo GTT)

VINNOVA

- EU collaboration:
  - AutoNet2030 (Contact: Katrin Sjöberg, Volvo GTT)
  - TEAM (Contact: Rafael Basso, Volvo GTT)
  - AdaptIVe (Contact: Malte Ahrholdt, Volvo GTT)

- Japan collaboration:
  - JARI platooning, concluded 2013 (Contact: Christian Grante, Volvo GTT)

- US collaboration:
  - PATH platooning FOT (Contact: Christian Grante, Volvo GTT)

Thank You for Listening!

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