On the Assessment of Active Safety Systems and Vehicle Stability using Objective Test Methods – Latest developments of eVALUE Project

Session: **D3-2 Active Safety Issues**
Paper reference: **F2010C176**
Author: **Josep Maria Dalmau**

Agenda

- eVALUE Project Presentation
- Test procedure development
  - Scenarios
  - Approach
  - C3-1
  - C3-2
  - C3-3
- Conclusions, Current Status & Next Steps

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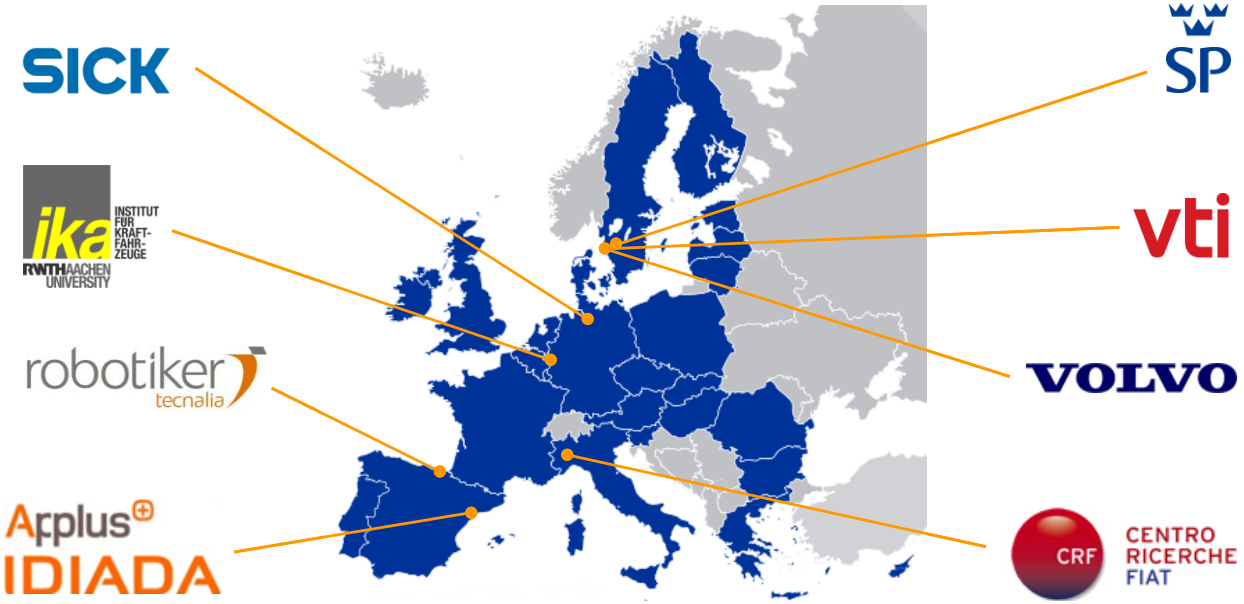
- **Project title**
  - eVALUE: Testing and Evaluation Methods for ICT-based Safety Systems
- **Duration**
  - Start: 1 January 2008
  - End: 31 December 2010
- **Consortium**
  - Partners: IKA, SP, VTI, VTEC, IDIADA, Tecnalia Robotiker, SICK, CRF



- **Objective**

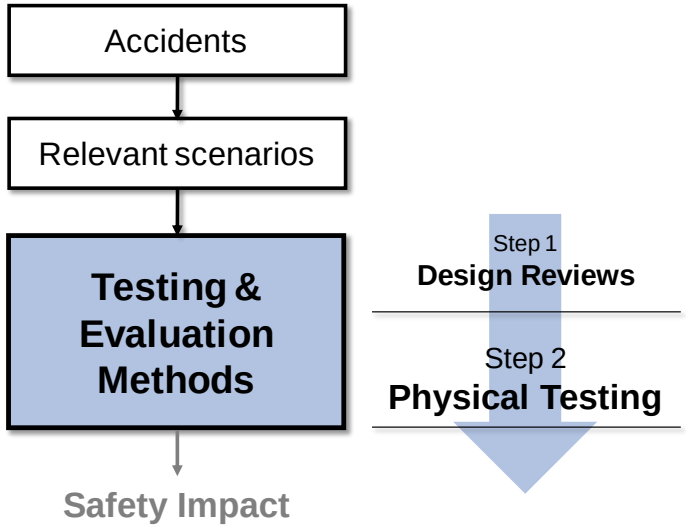
To develop testing and evaluation methods for ICT-based safety systems.

AND thereby

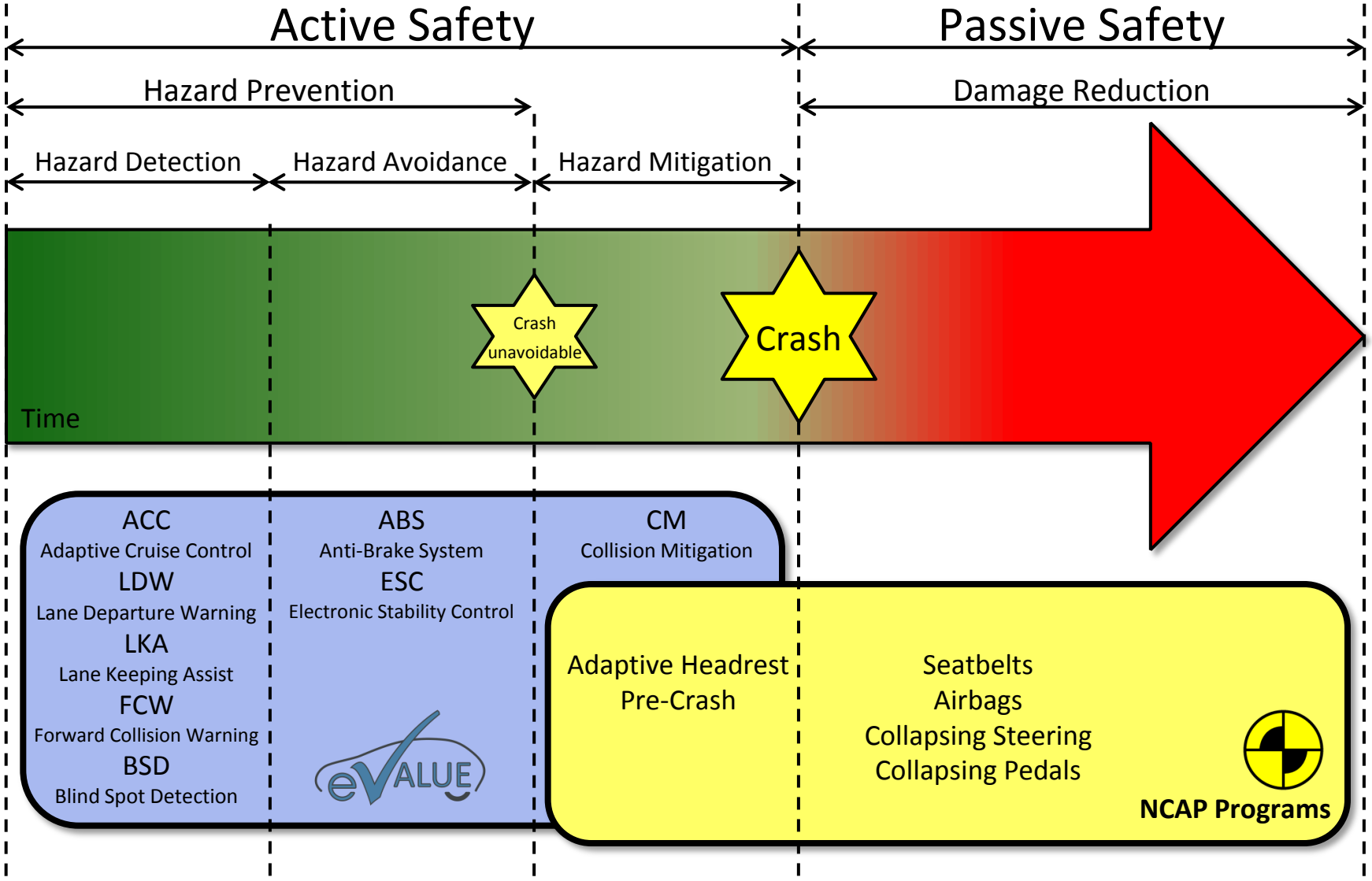
To increase public perception and customer acceptance of ICT-based safety systems.

To support development of ICT-based safety systems at vehicle OEMs and suppliers.

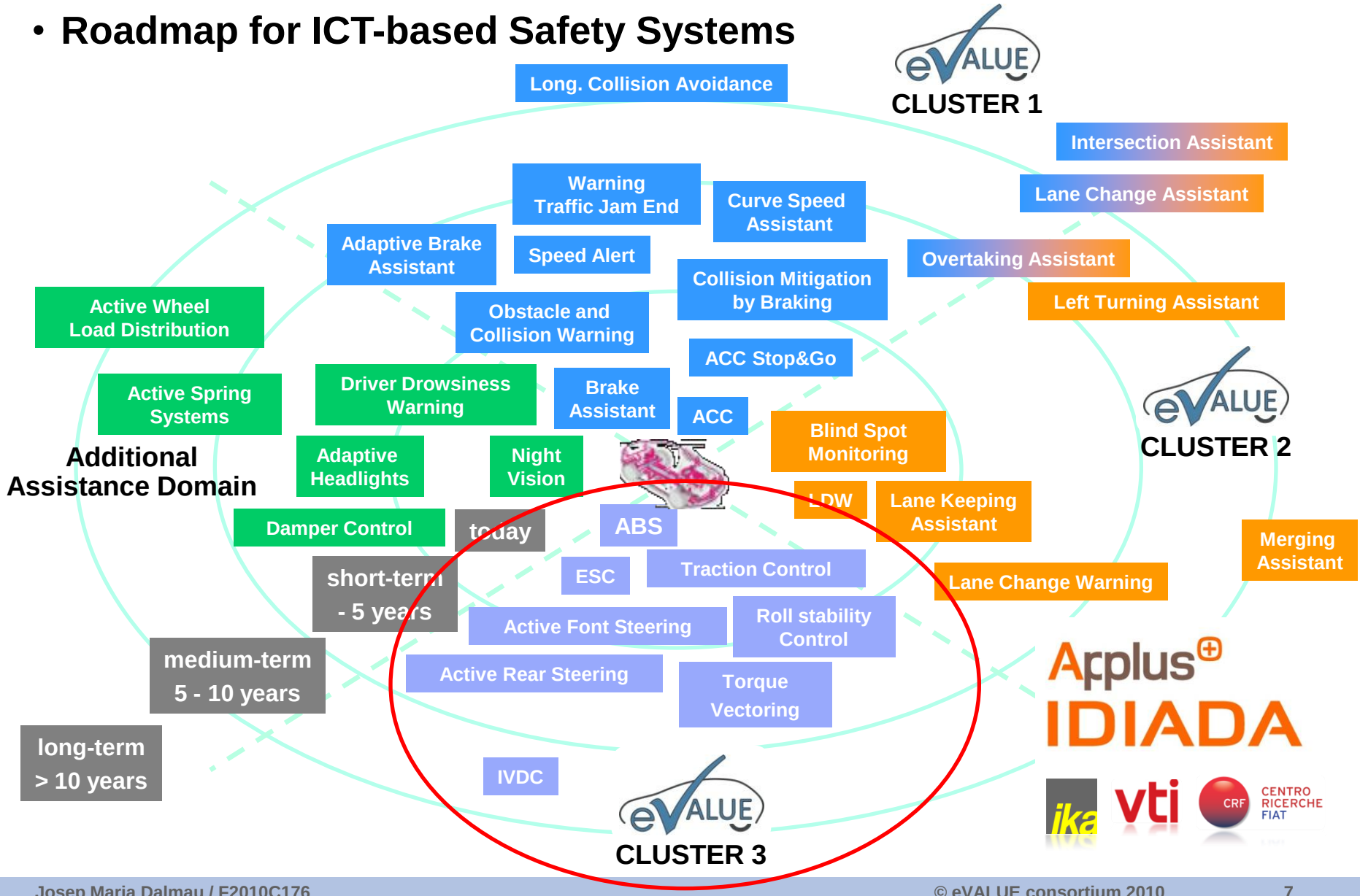
- **Approach**



- **Scope**



- **Roadmap for ICT-based Safety Systems**



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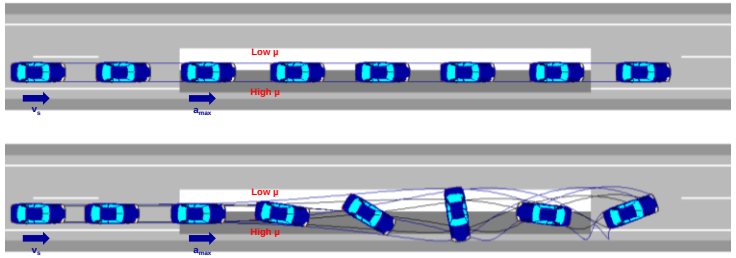
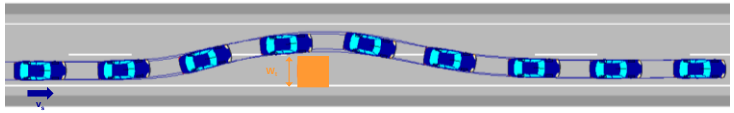
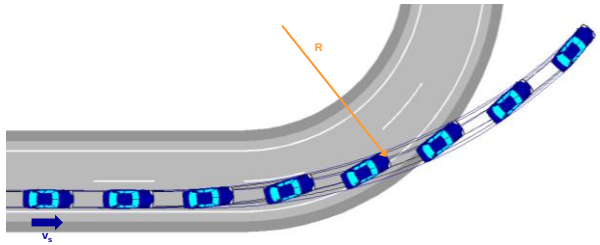
- **Scenarios**

Code	Description	Figure
C3-1	Emergency braking on asymmetric adherence (mu split)	
C3-2	Obstacle avoidance (double lane change)	
C3-3	Entering a corner too fast (highway exit)	

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Test procedure development

- **General eVALUE approach**
  - Define objective evaluation test procedures and performance criteria
  - Regard active safety of vehicles as such (not at system level)
  - Not in the eVALUE scope:
    - Definition of fail/pass criteria
    - Direct standardisation of testing
- **Cluster 3 approach**
  - C3-1 and C3-2: based on international standard test procedures (manoeuvres)
    - eVALUE: test procedure enhancement for wider safety assessment
  - C3-3: no international standard test procedure available
    - eVALUE: complete new development right from test manoeuvre definition
  - Challenges: result **normalisation** in order to avoid track/grip dependancy and adapt the assesment to the different vehicle types

"The test vehicle sets its own target on the proving ground used"

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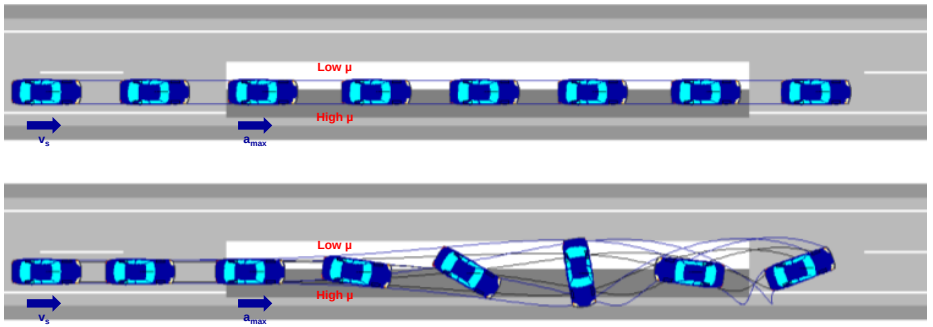
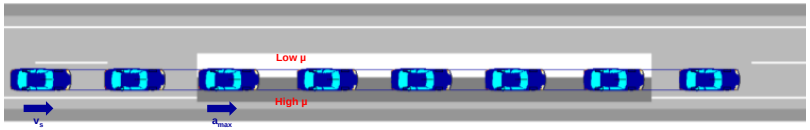


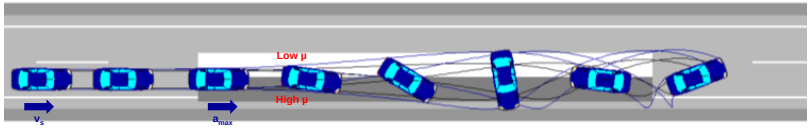
- **C3-1 Emergency braking on asymmetric adherence**

- Closed loop test: mu split braking (open loop under development)
- Performance criteria: good compromise between stopping distance and stability (steering correction)



<u>Criteria privileged: Stability</u>

High-mu wheel pressures are too much controlled. Vehicle remains stable and easy to control but the braking performance is very poor.



<u>Criteria privileged: Stopping distance</u>

Fast and big steering correction requested to keep vehicle stable.

Driver is overwhelmed and vehicle starts to spin out.

- **C3-1 Emergency braking on asymmetric adherence**
  - Test procedure

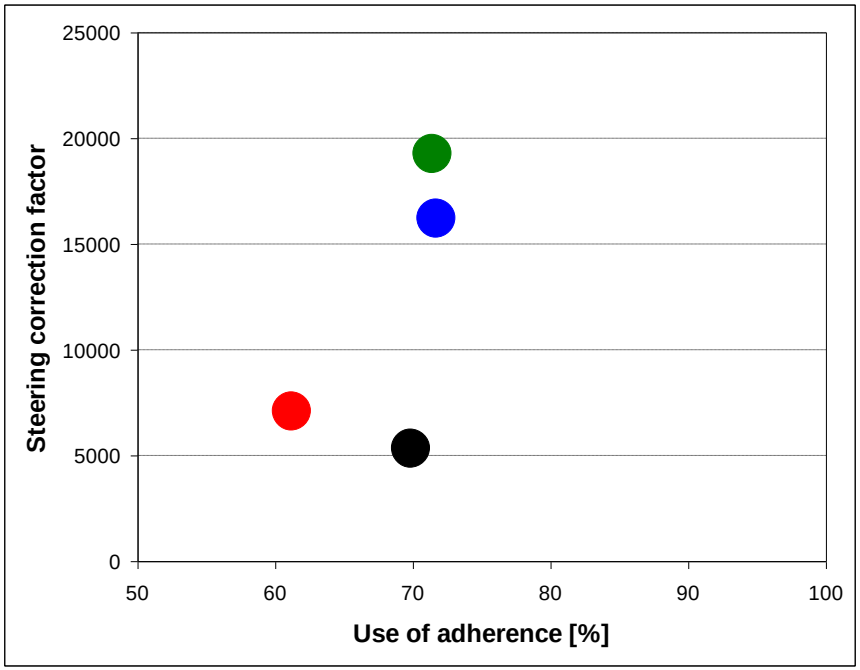
Test manoeuvre	Surface	Speed	Conditions for valid runs
1. Preliminary braking on high mu	Wet asphalt	80 to 0 kph	0.5 seconds before brake application Initial brake temperature ≈ 100 ºC Yaw rate within ± 1 deg/s Steer angle within ± 3 deg Panic brake application Pedal force build up to more than 50 daN Pedal application rate over 300 daN/s Driver steering correction 0.3 seconds after brake application and/or after initial yaw response (no anticipation)
2. Preliminary braking on low mu	Wet ceramic	60 to 0 kph	
Normalisation 3. Mu split braking	Split: wet asphalt/ wet ceramic	100 to 0 kph	

- **C3-1 Emergency braking on asymmetric adherence**
  - Analysis

Indicator	Formula	Description
Use of adherence	$\varepsilon_{musplit} = \frac{teorSD}{musplitSD}$ **Normalisation**	teorSD: theoretical stopping distance calculated using the average deceleration between high and low mu preliminary braking manoeuvres musplitSD: stopping distance using the deceleration in the mu split braking manoeuvre Note: both deceleration and stopping distance are calculated according to ISO 21994
Steering correction factor	$SCF = MaxSWA \cdot MaxSWR$	MaxSWA: maximum steering wheel angle MaxSWR: maximum steering wheel rate

- **C3-1 Emergency braking on asymmetric adherence**
  - Results

Class	Body	Engine	Gearbox	Systems	Display
Small family	5 door hatchback	1.6 petrol	Manual	ESC	●
Executive	4 door saloon	2.2 diesel	Automatic	ESC	●
Small family	5 door hatchback	Hybrid	CVT	ESC	●
Executive	5 door saloon	3.0 petrol	Automatic	ESC + AFS	●



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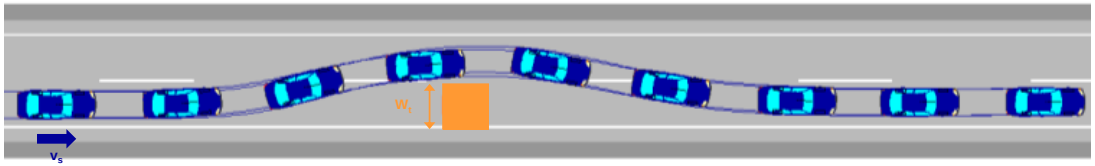
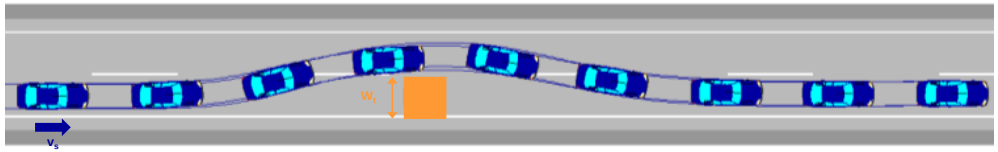
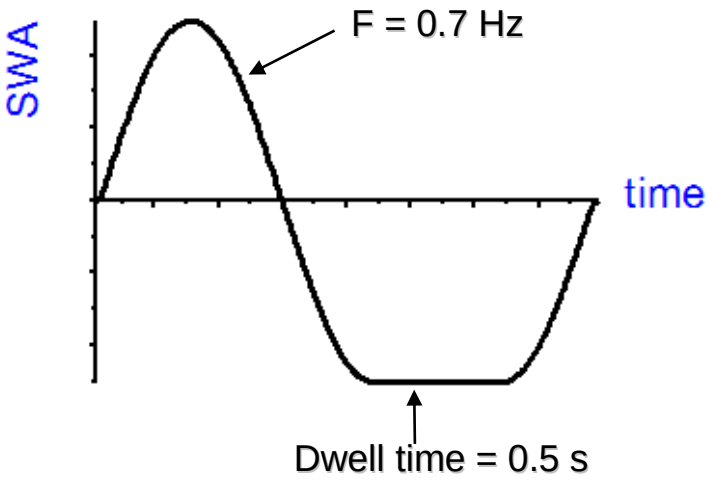
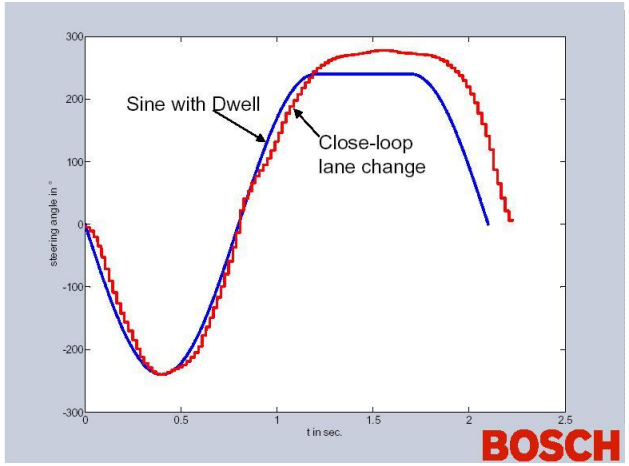


- **C3-2 Obstacle avoidance**



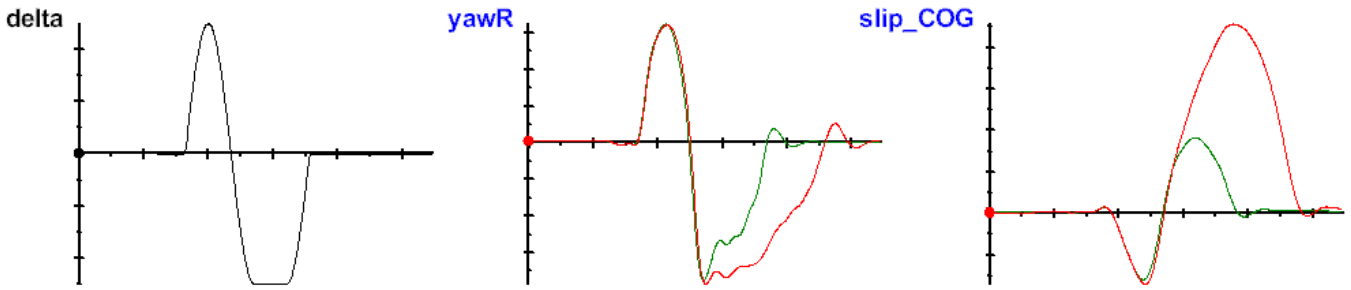
- Open loop test: Dwell sine (FMVSS 126 procedure)
- Performance criteria: good compromise between stability and lateral response (FMVSS 126) and additional indicators (eVALUE)





Both dwell time and frequency are based on analysis of real driving situations

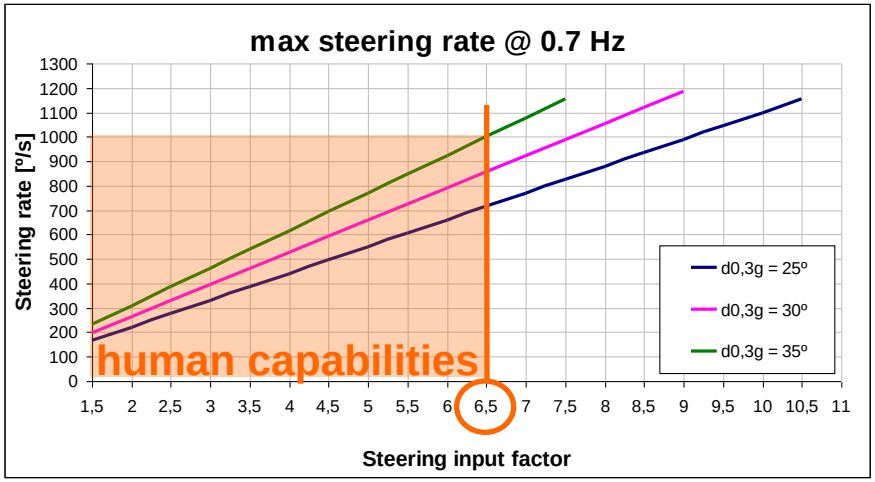
- **C3-2 Obstacle avoidance**
  - Dwell sine animation ESC ON/OFF

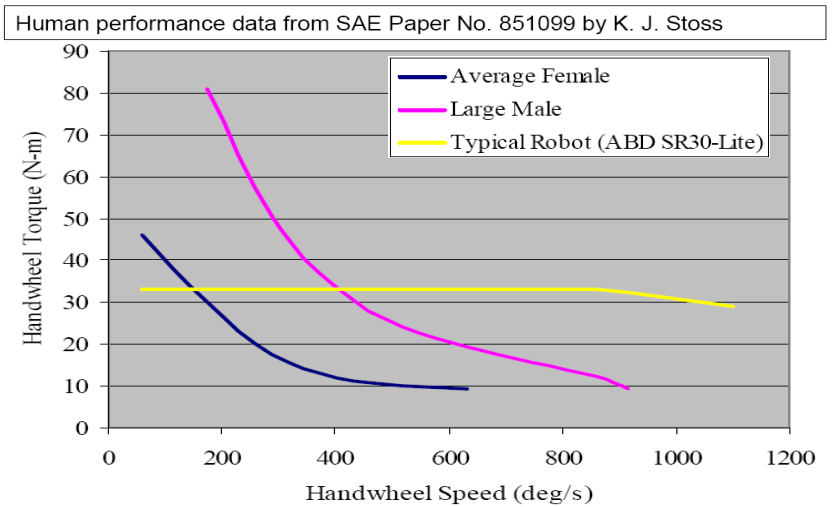


ESC off **ESC on**

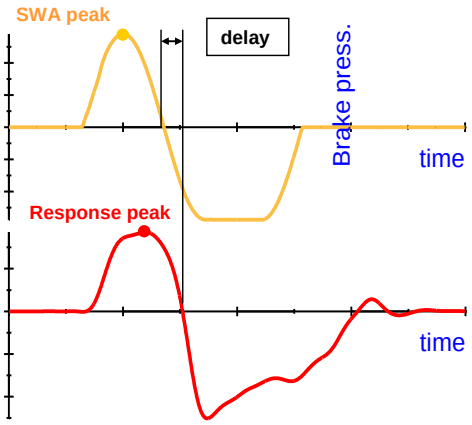
Animation

- **C3-2 Obstacle avoidance**
  - Test runs to consider: steering rate within human capabilities (6.5 input factor)

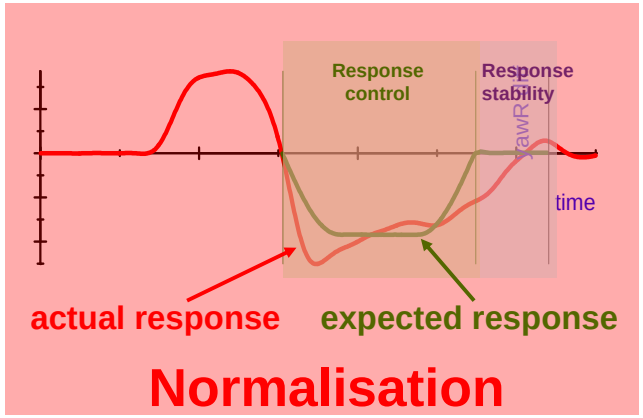




  - New indicator: driver intention following (based on ESC principle)



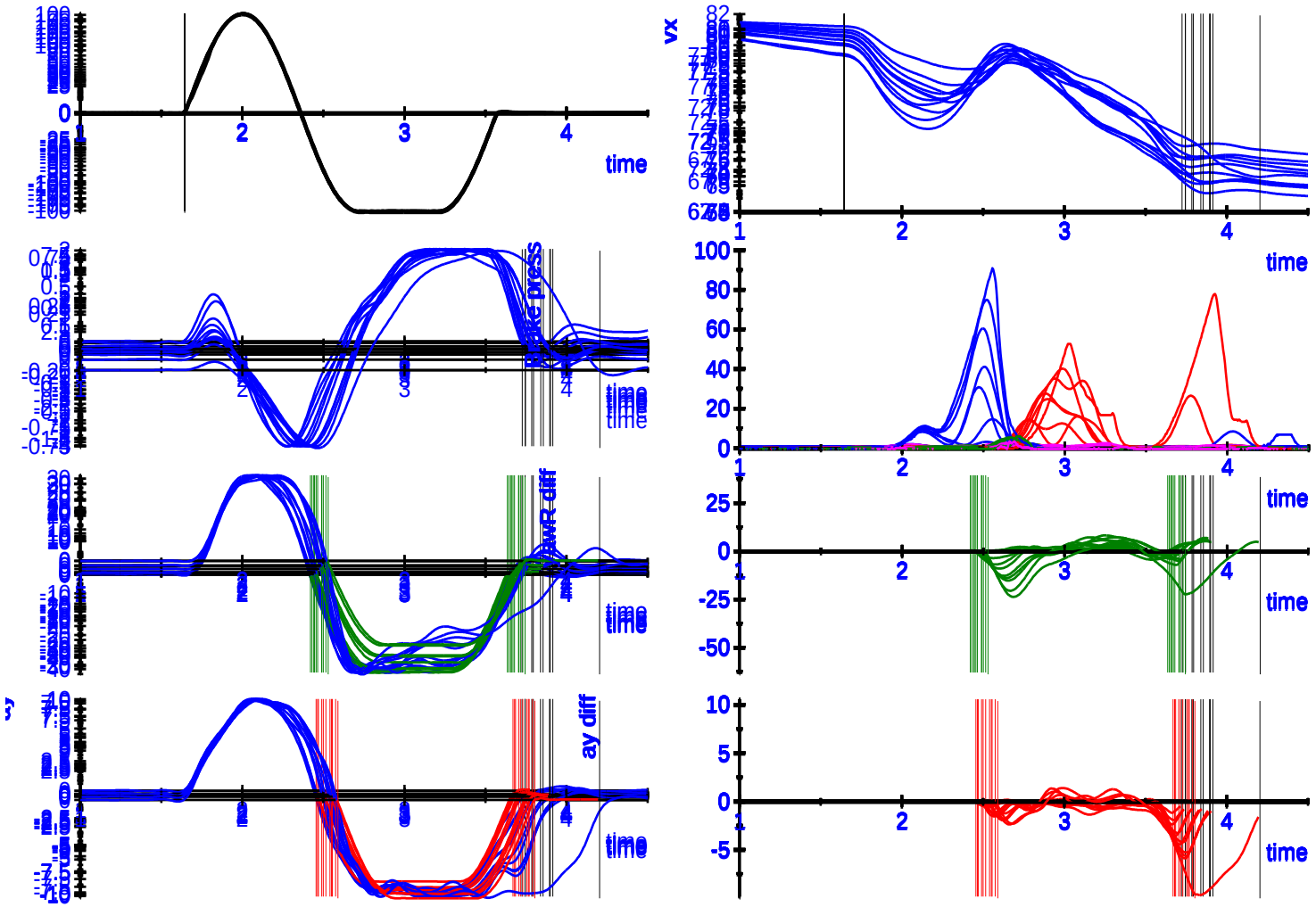
Response gain = Response peak / SWA peak



"an effective ESC makes the car respond according to the driver's intention"

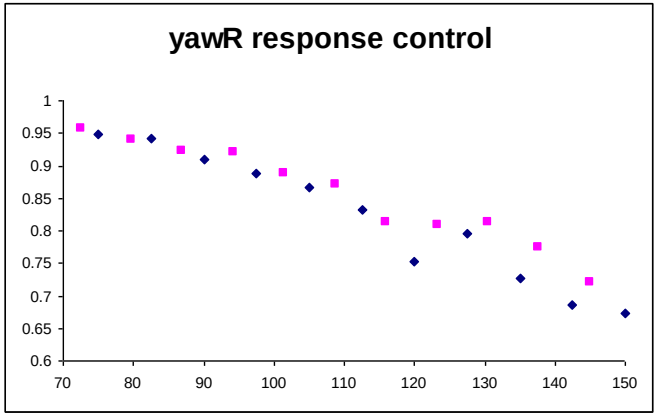
Test procedure development

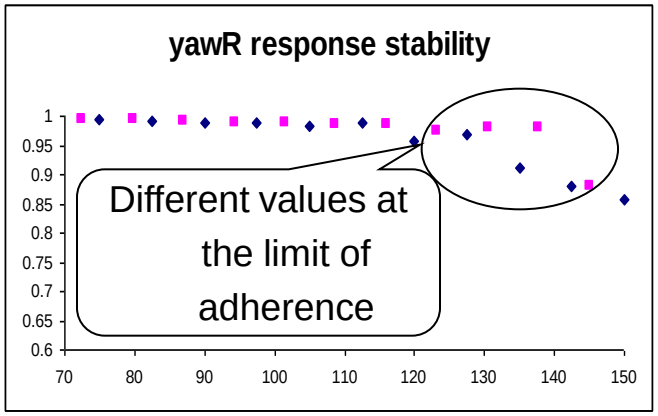
- **C3-2 Obstacle avoidance**
  - Test runs series



- **C3-2 Obstacle avoidance**
  - Test result consistency among different proving grounds (IDIADA)

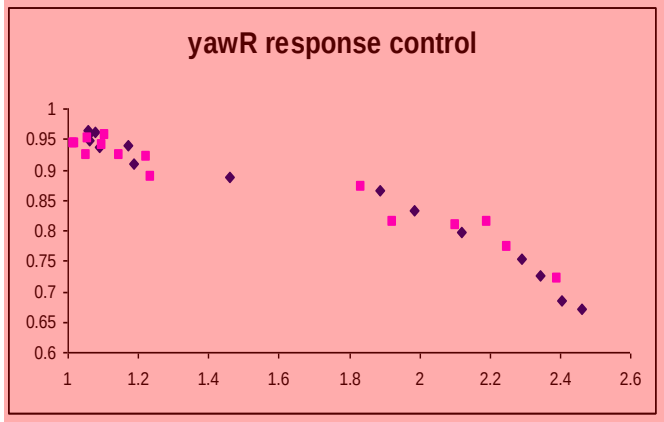
Indicator results vs SWA

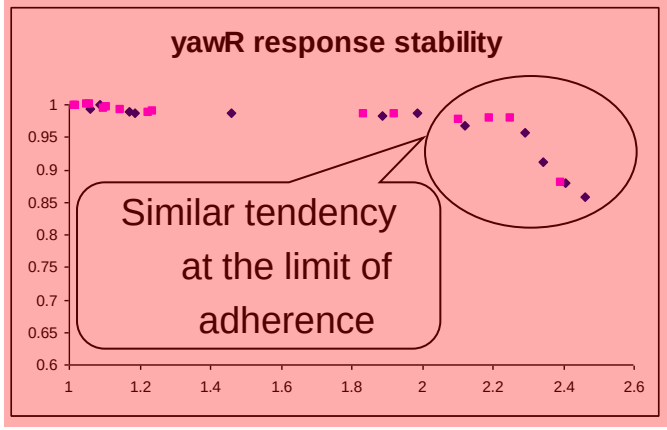




Indicator results vs TL_1

$$TL_1 = \frac{\dot{\psi} \cdot v_x}{a_y}$$





$TL_1 = 1$ (steady state)
$TL_1 > 1$ (transient)
Taken at 2nd yawR peak

Dynamic Platform A
versus
Dynamic Platform B

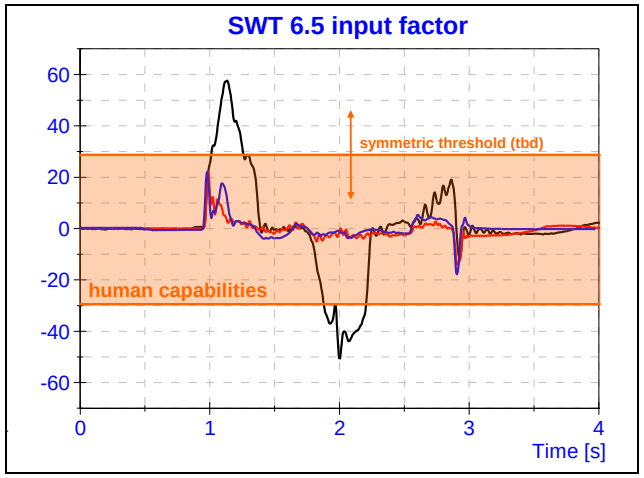
Normalisation

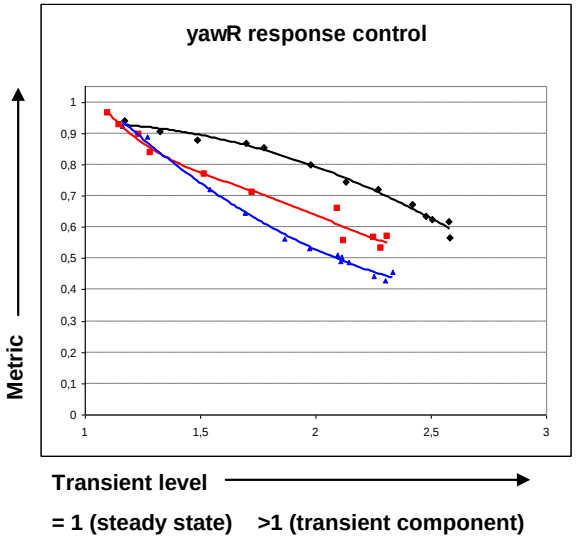
- **C3-2 Obstacle avoidance**
  - Analysis

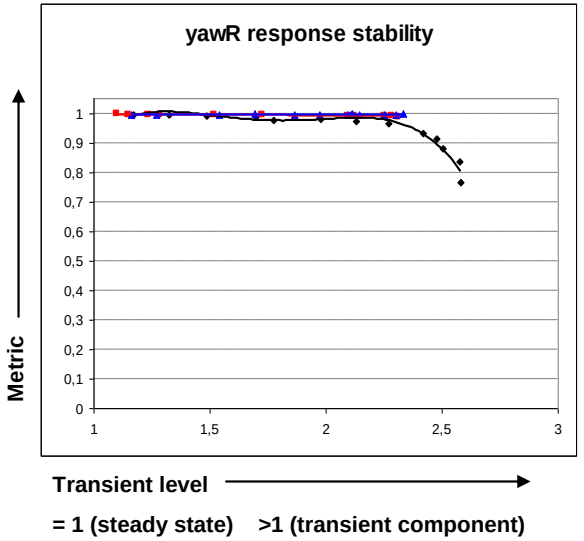
Indicator	Formula	Description
Steering wheel torque	SWT	SWT: steering wheel torque evolution. It must be within human capabilities in test runs up to 6.5 input factor (threshold to be determined)
Driver intention following	$DIF = 1 - \frac{\int difference}{\int expected}$ **Normalisation**	DIF: ratio between response difference area vs expected response area. Good metric ≈1 Poor metric < 1
Wheel lift	WL	WL: indicator based on wheel height in order to assess roll stability. Rollover condition is carried over from NHTSA's fishhook test procedure

- **C3-2 Obstacle avoidance**
  - Results

Class	Body	Engine	Gearbox	Systems	Display
Large family	5 door MPV	2.7 diesel	Manual	ESC	●
Large family	4 door saloon	2.2 diesel	Manual	ESC	●
Small family	5 door MPV	1.5 petrol	Manual	ESC	●







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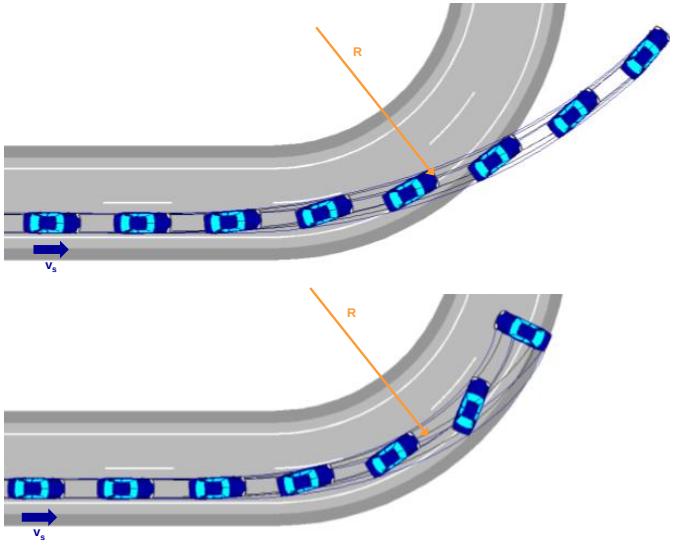
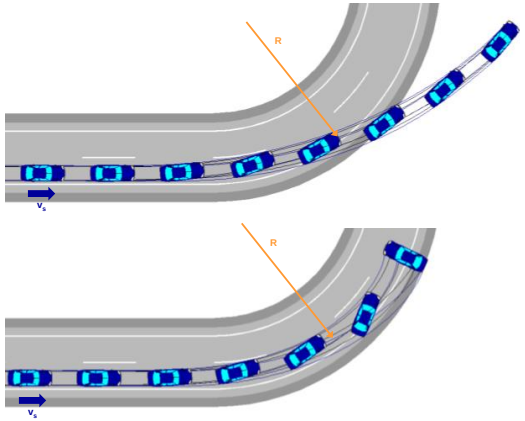


- **C3-3 Entering a corner too fast**

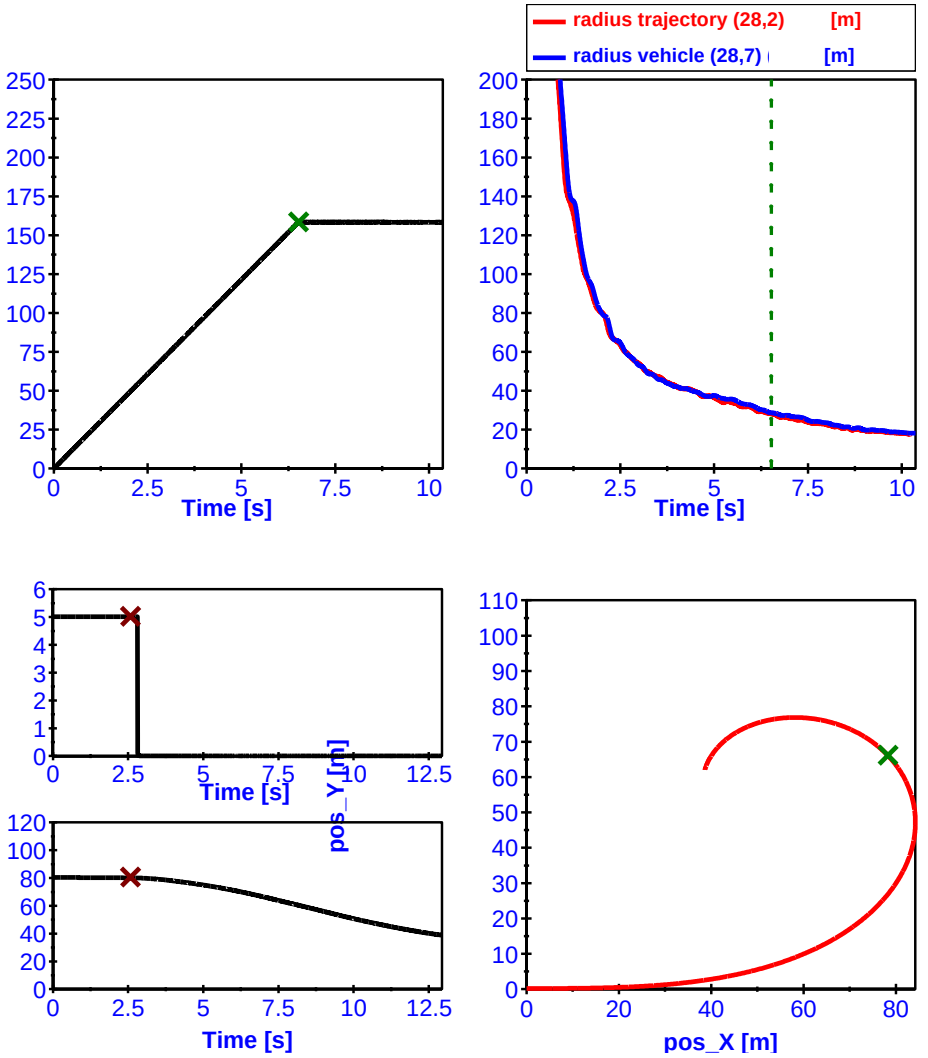


- Performance criteria: good compromise between stability and lateral response and additional indicators (eVALUE)
- Test procedure: Highway exit (eVALUE procedure). Open loop test.

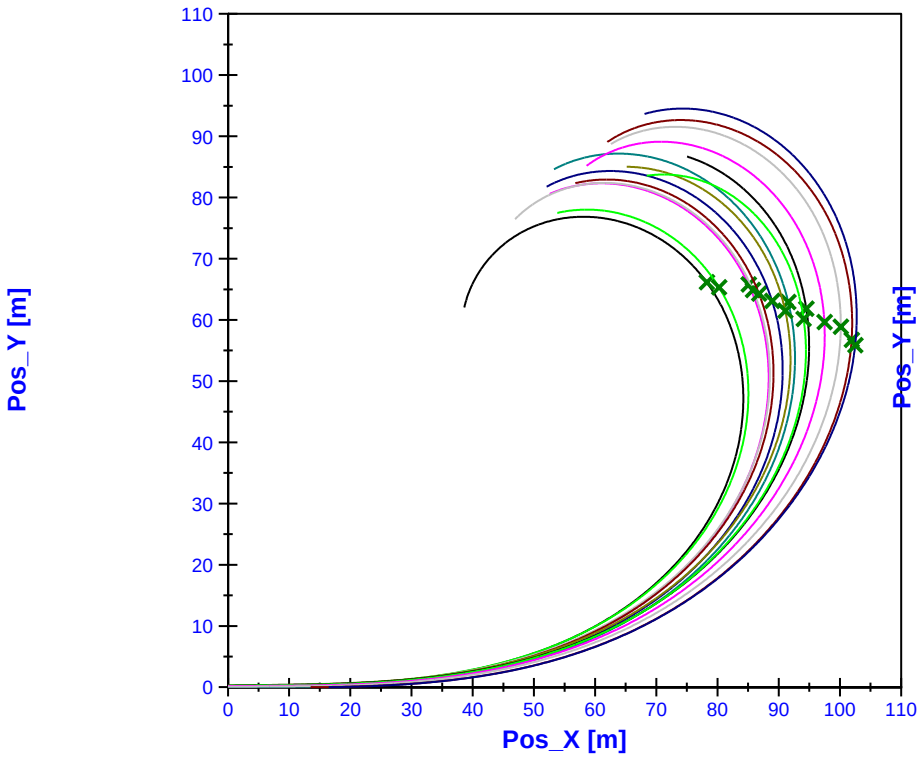
Test manoeuvre	Test run	Steer	Speed	Additional conditions
Steering wheel ramp	Initial (1)	Rate: 0,3 g/s Angle: 0 to 6.5·δ0.3g	80 kph	At steering ramp start Release throttle pedal Gear Highest or D
	Successive (i)	Rate: increased at 2% Angle: 0 to 6.5·δ0.3g	increased at 2% final speed: 100 - 120 kph	

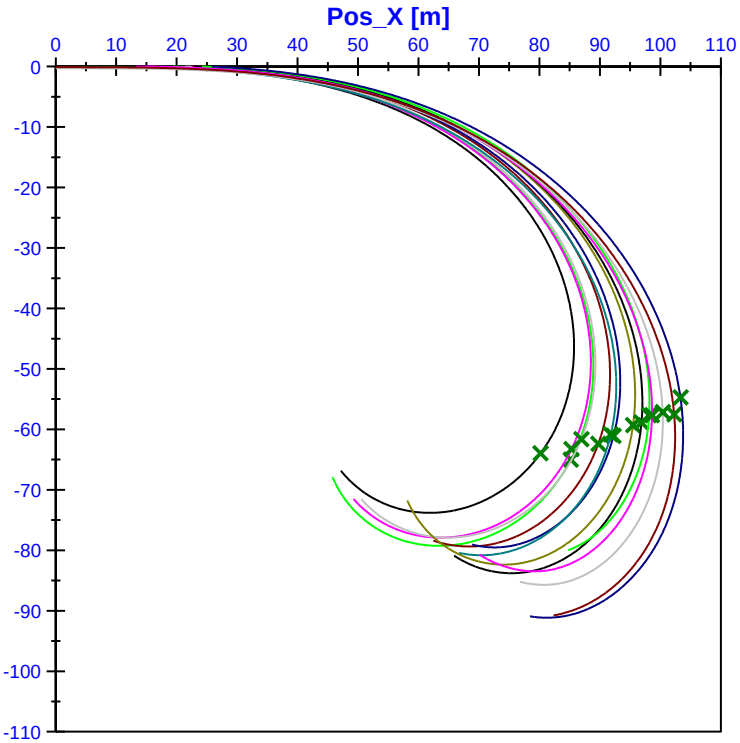
Normalisation

- **C3-3 Entering a corner too fast**
  - Time history example
  - Green crosses and green line mark the end of the SW input (ramp). Ri is determined at this moment
  - Brown crosses mark the beginning of the SW input (ramp)
  - Pedal (throttle) is released at the beginning of the SW input (ramp).
  - Radius trajectory (in red) is derived from X,Y position (running circular regression).
  - Radius vehicle (in blue) is calculated based on vehicle velocity and yaw rate.



- **C3-3 Entering a corner too fast**
  - Trajectory evolution





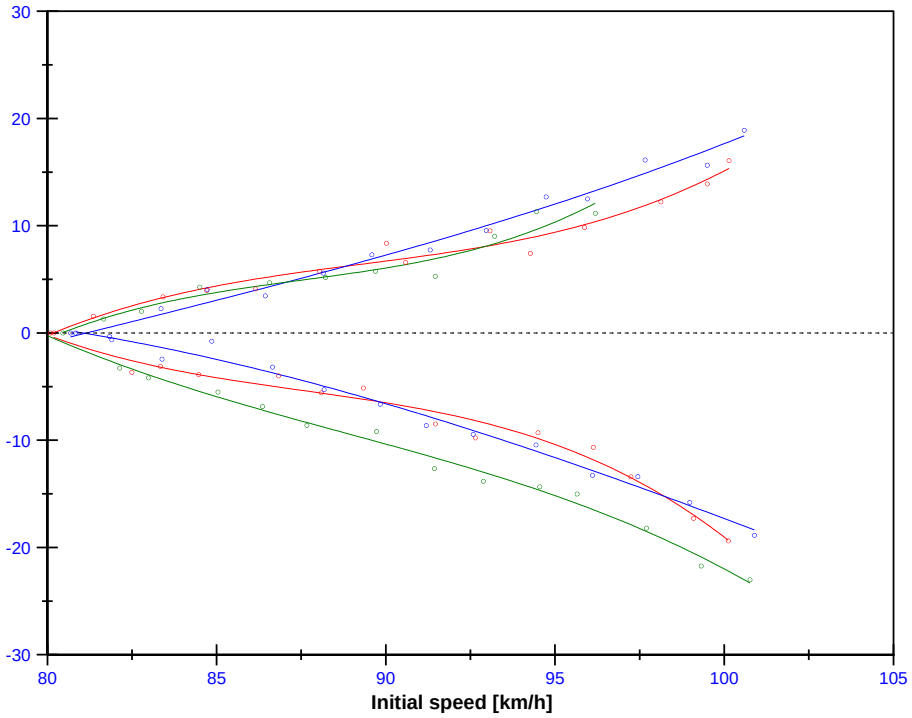
  - Green crosses mark the end of the SW input (ramp) of each test run.
  - As initial speed is increased, radius also increases (keeping SWA constant).

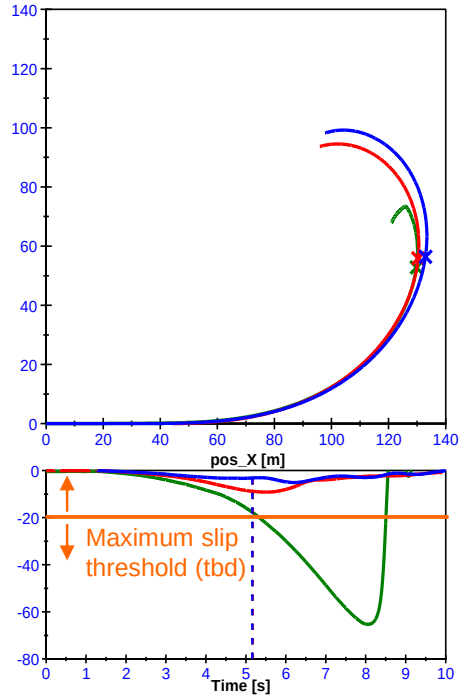
- **C3-3 Entering a corner too fast**
  - Analysis

Indicator	Formula	Description
Relative radius	$\mathrm{Re}\,l_R = R_i - R_1$ **Normalisation**	Rel$_R$: difference between the trajectory radius in the test run (i) and the trajectory radius in the initial test run (1). In all cases, radius measurement is taken at the end of the steering wheel ramp.
Slip	$Slip_{COG}$	Slip$_{COG}$: slip angle at the center of gravity of the vehicle. It is used as oversteer (loss of control) indicator. (threshold to be determined)
Wheel lift	WL	WL: indicator based on wheel height in order to assess roll stability. Rollover condition is carried over from NHTSA's fishhook test procedure

- **C3-3 Entering a corner too fast**
  - Results

Class	Body	Engine	Gearbox	Systems	Display
Small family	5 door hatchback	1.6 petrol	Manual	ESC	●
Executive	4 door saloon	2.2 diesel	Automatic	ESC	●
Small family	5 door hatchback	Hybrid	CVT	ESC	●





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Conclusions, Current Status & Next Steps

- **Conclusions**
  - It is possible to evaluate vehicle active safety performance by using objective test methods.
  - The strong focus on repeatability and result normalisation with respect to test track and vehicle type, make these test procedures suitable to be adopted by any organisation wanting to assess vehicle active safety performance.

- **Current Status**
  - Draft testing protocols and intended indicators under validation.

- **Next steps**
  - Test protocols finalised in October 2010.
  - Final demonstration event on 24 and 25 November 2010 at Applus IDIADA (Spain).

THANK YOU VERY MUCH FOR YOUR KIND ATTENTION

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