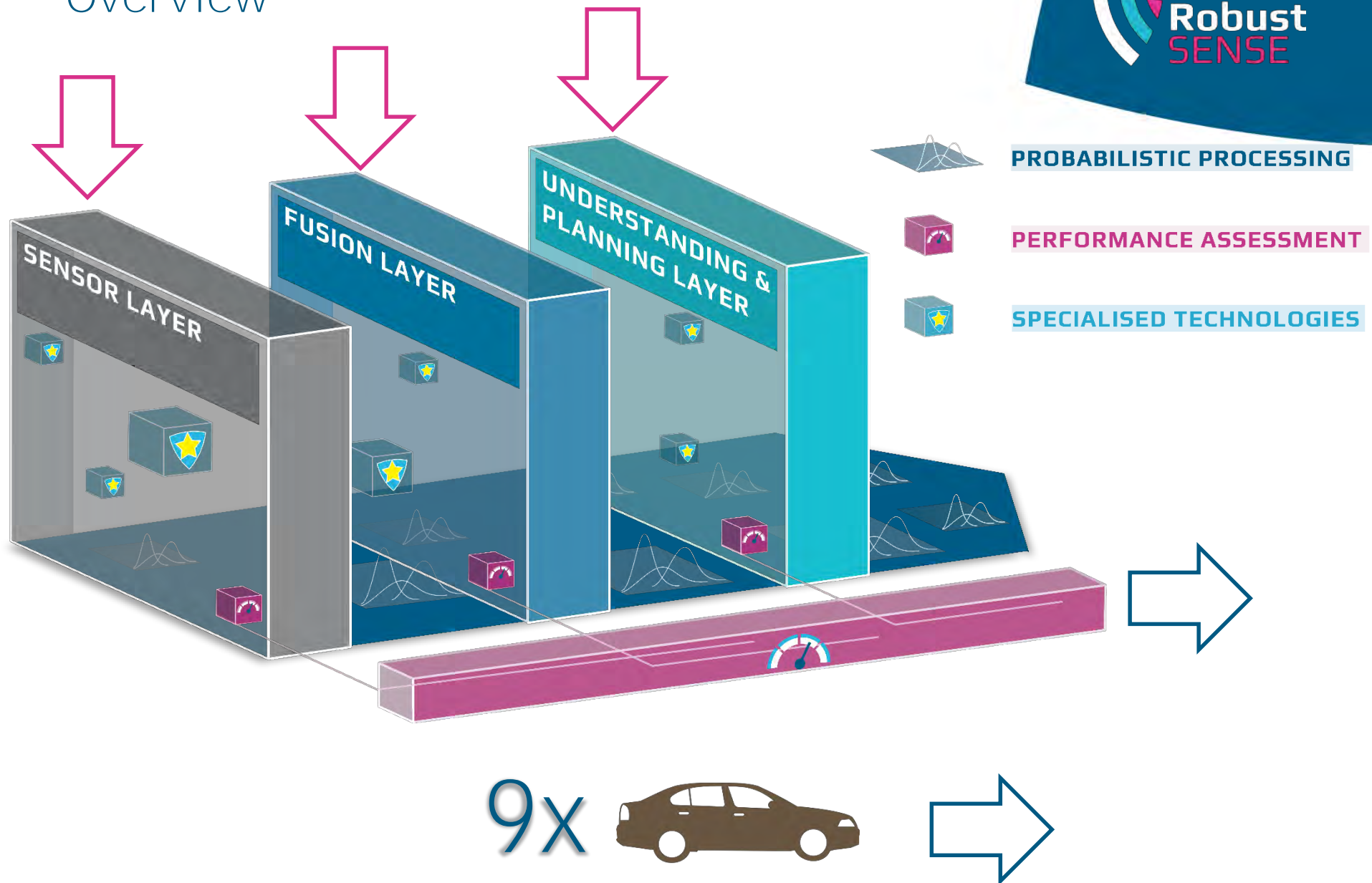




## Prototypes and Testing

Pablo Mejuto (CTAG)  
Ulm, Germany

# Overview



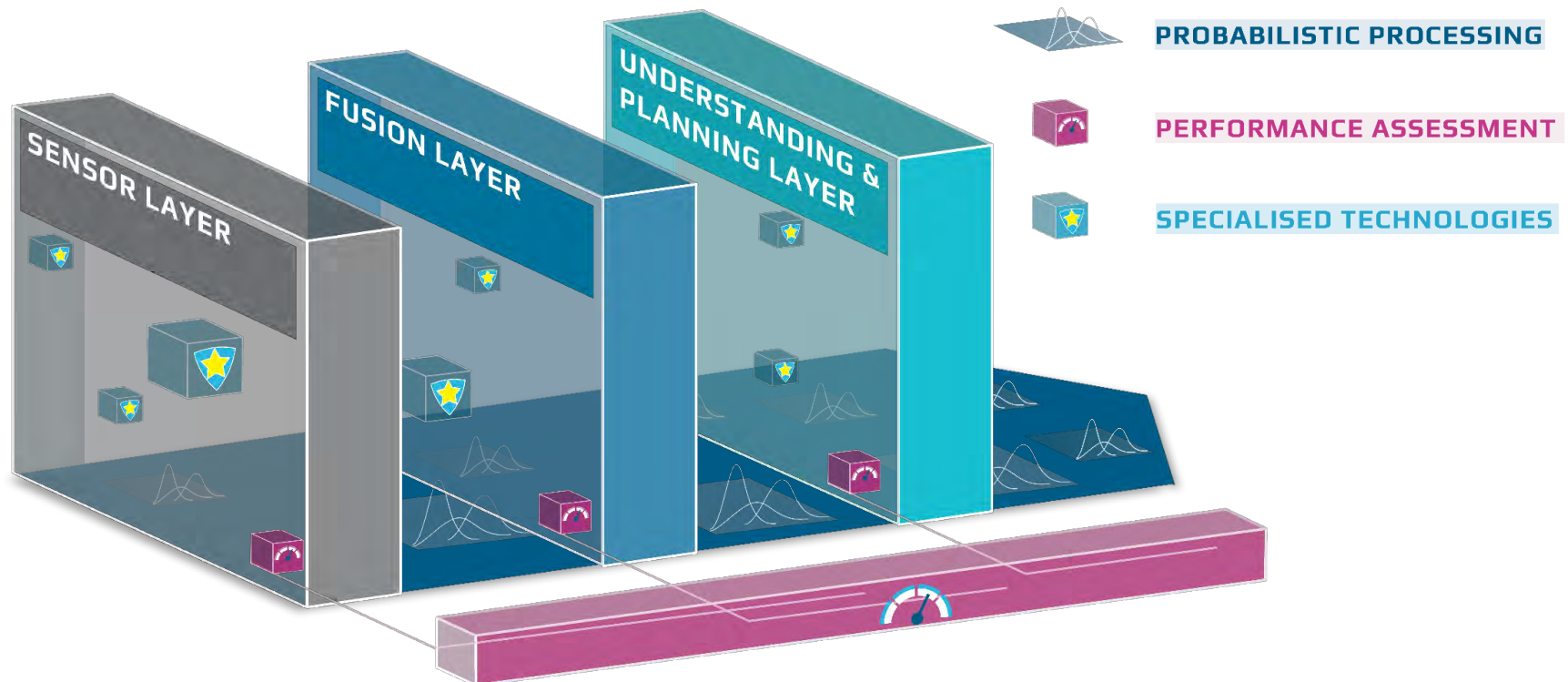
# Objectives

- ▼ Development the System Performance Assessment Module
- ▼ Integration and pre-test of sensor perception platforms
- ▼ Integration of all the developments in the demonstration prototypes
- ▼ Tests of the RobustSENSE perception platform and results

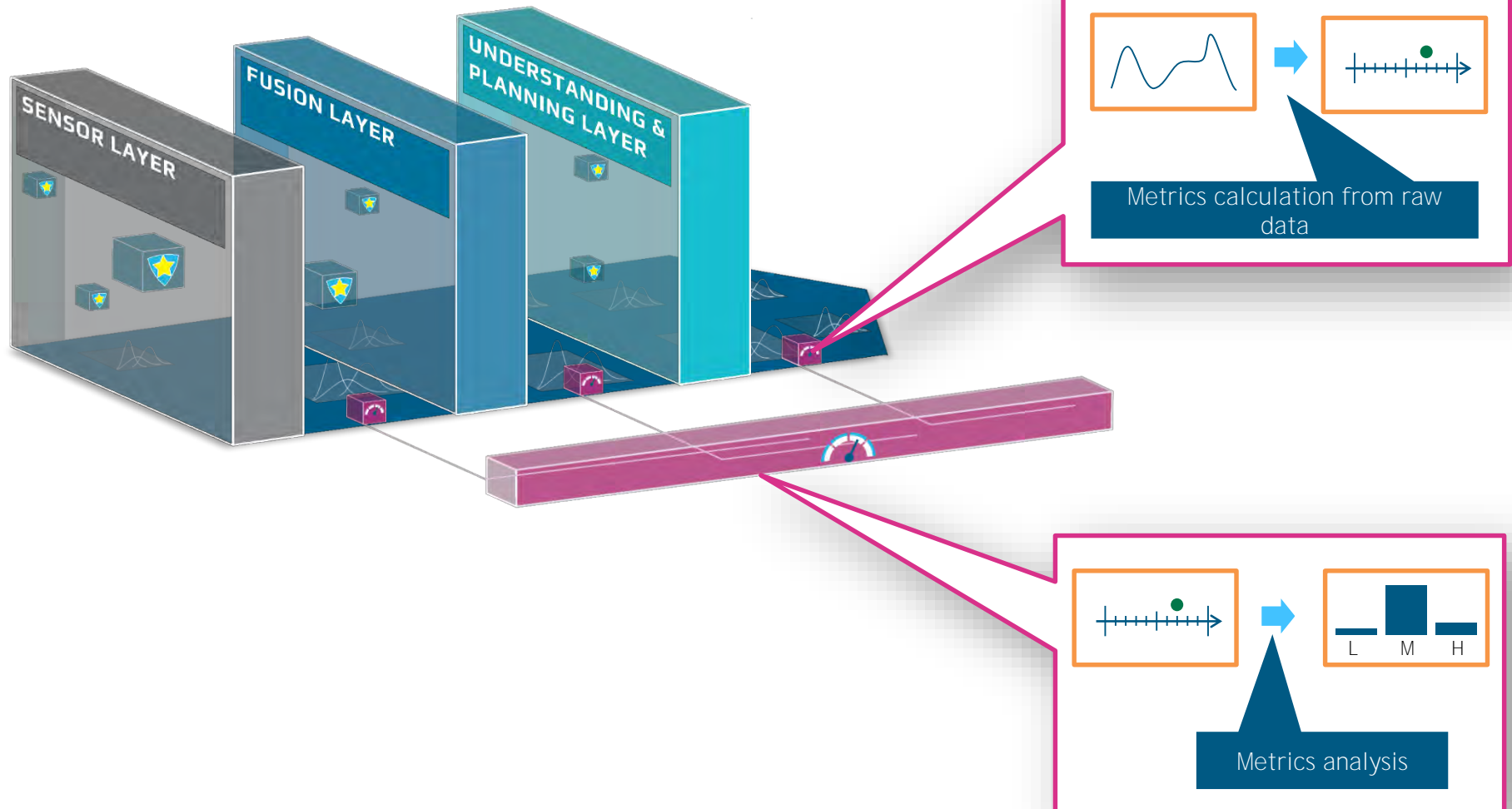
# SUMMARY WORK DONE

# System performance assessment module

- ▼ Software module able to determine the global perception platform status and its LEVEL OF RELIABILITY during the execution by means of a collection of metrics from the RobustSENSE platform

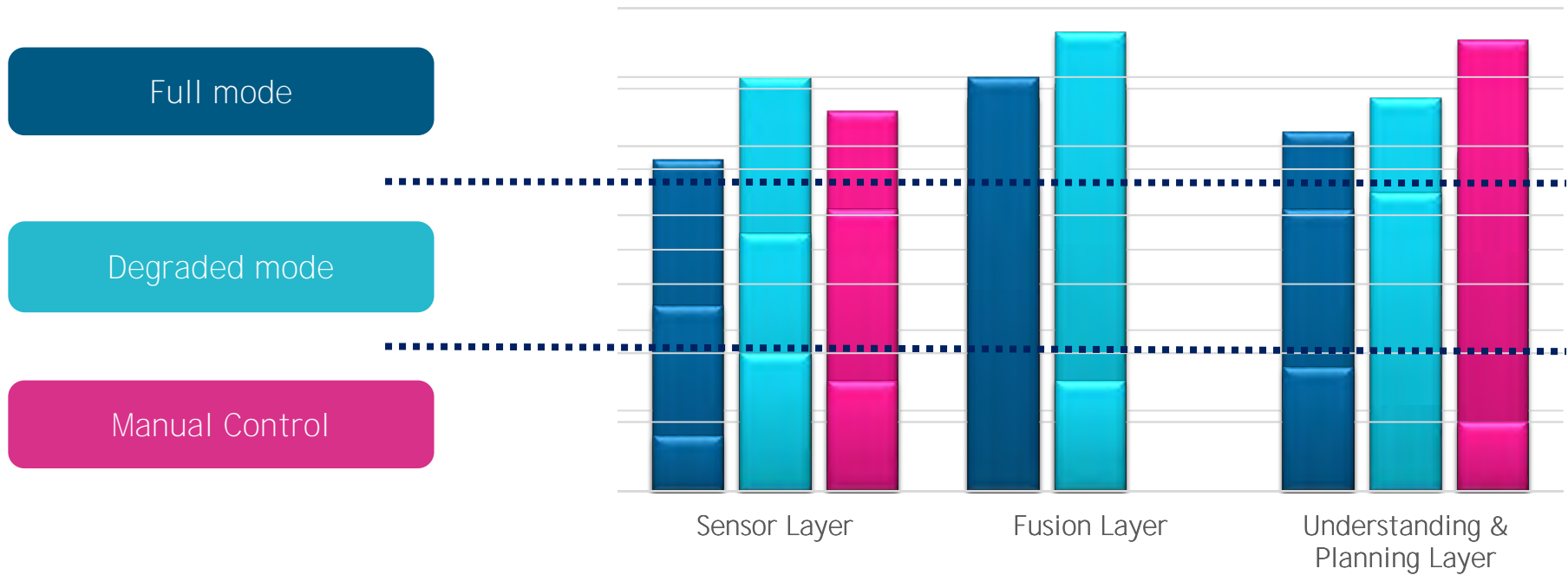


# System performance assessment module

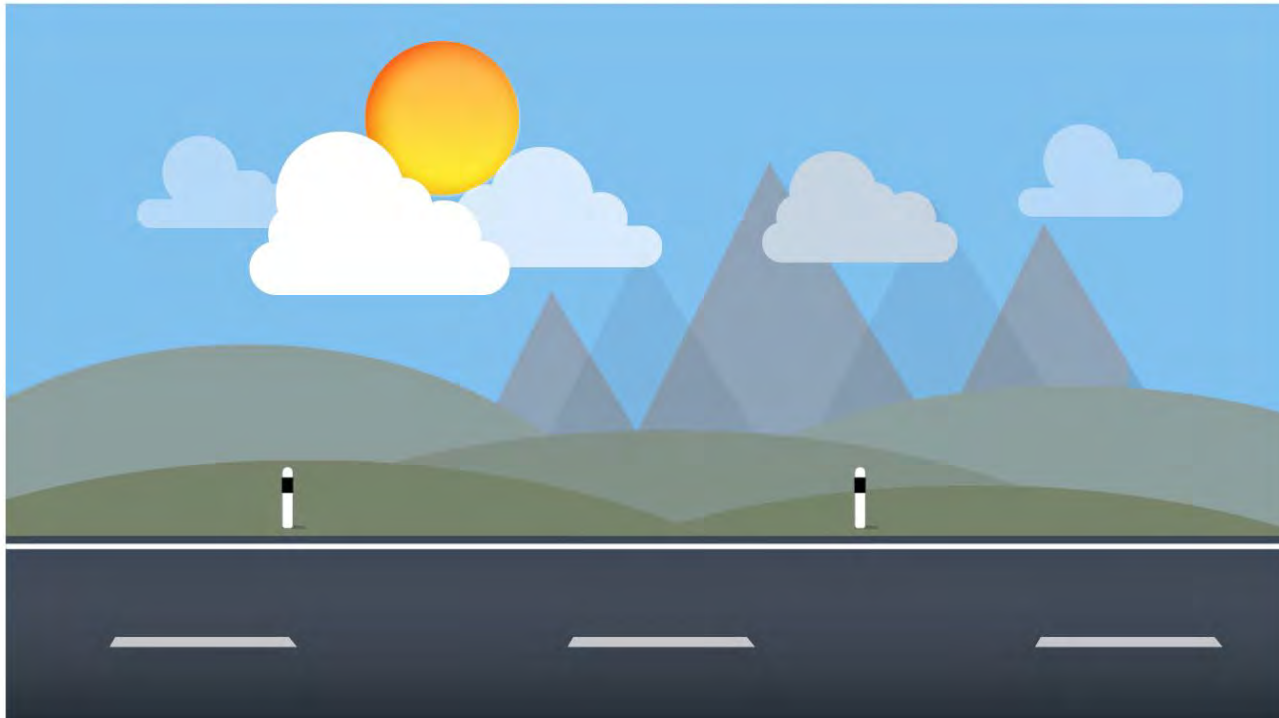




## System Performance Assessment Values

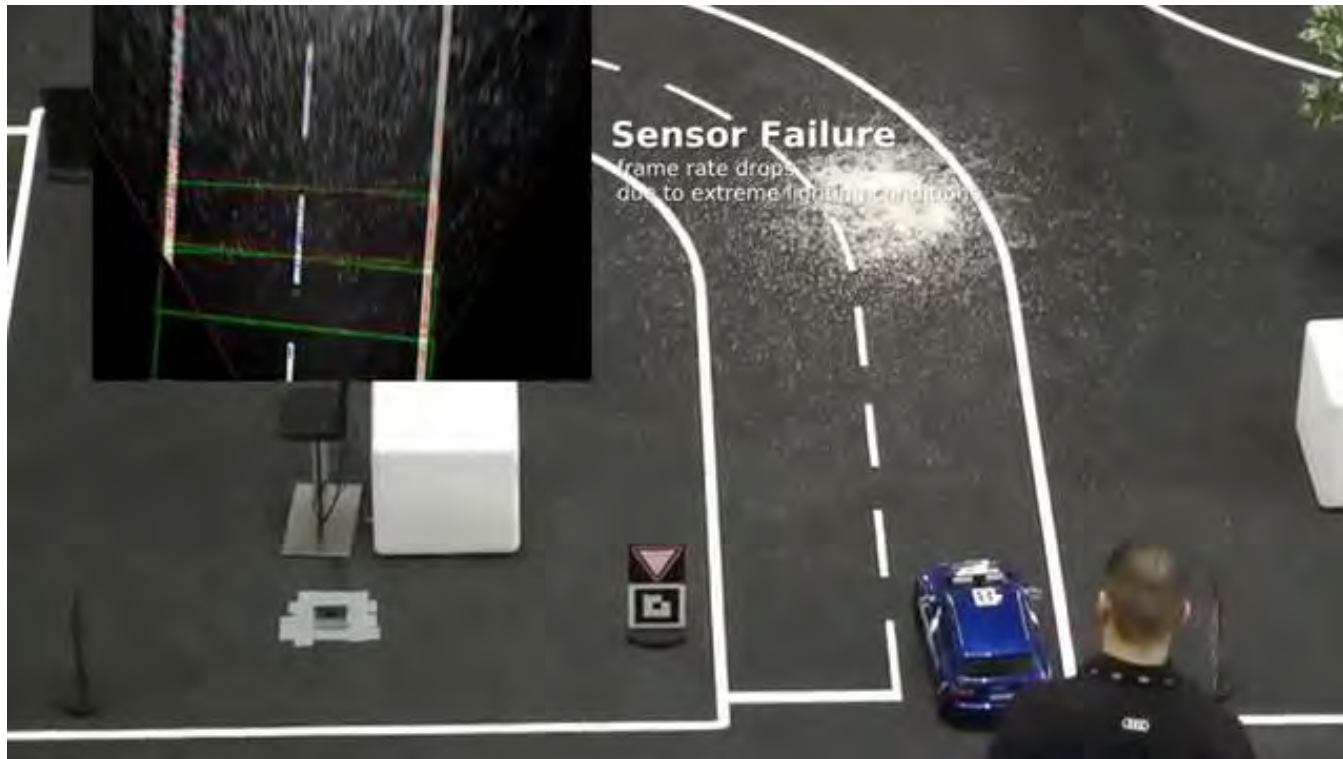


## ▼ Degradation on Safety GAP

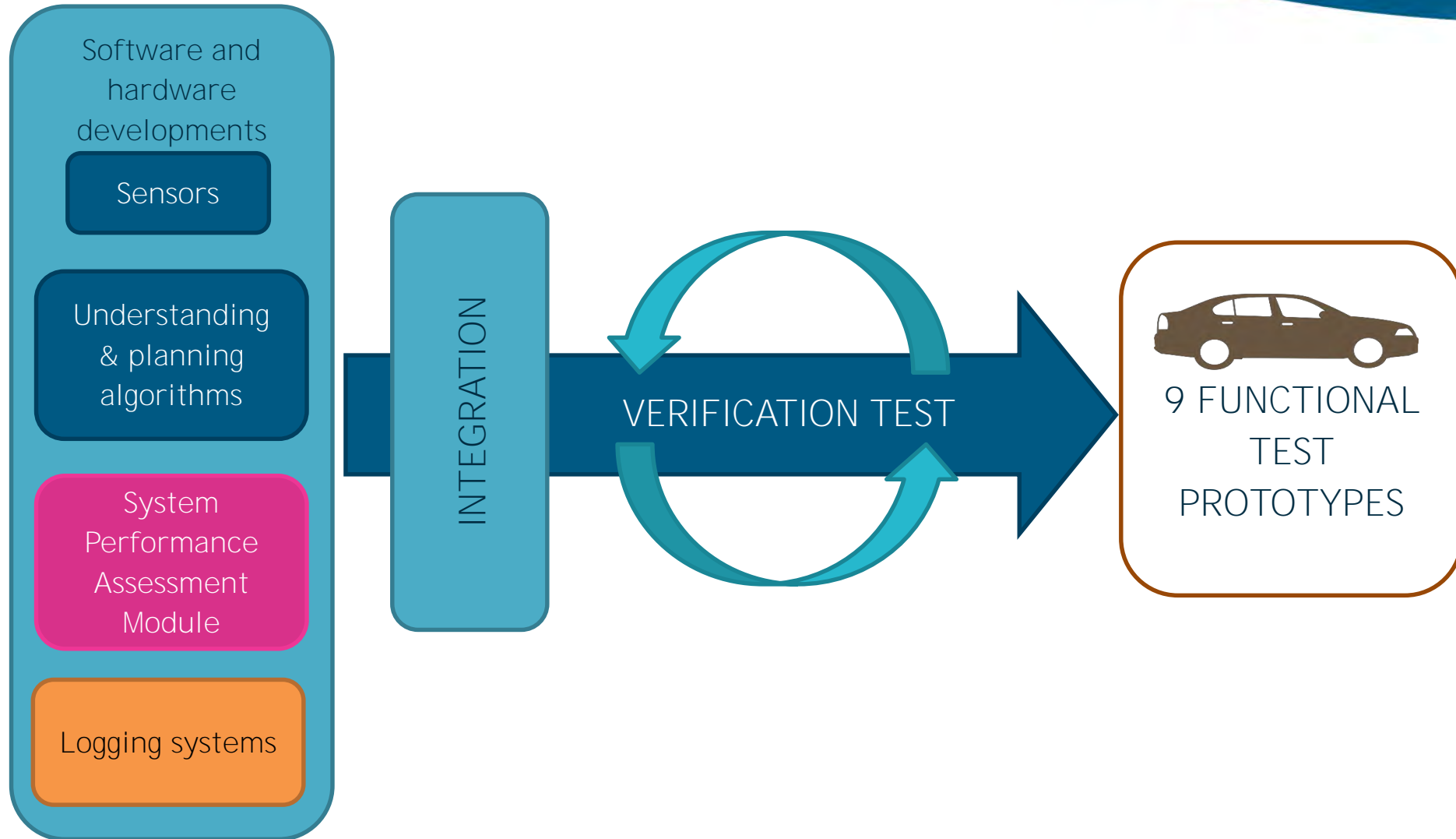




## ▼ Degradation on Speed



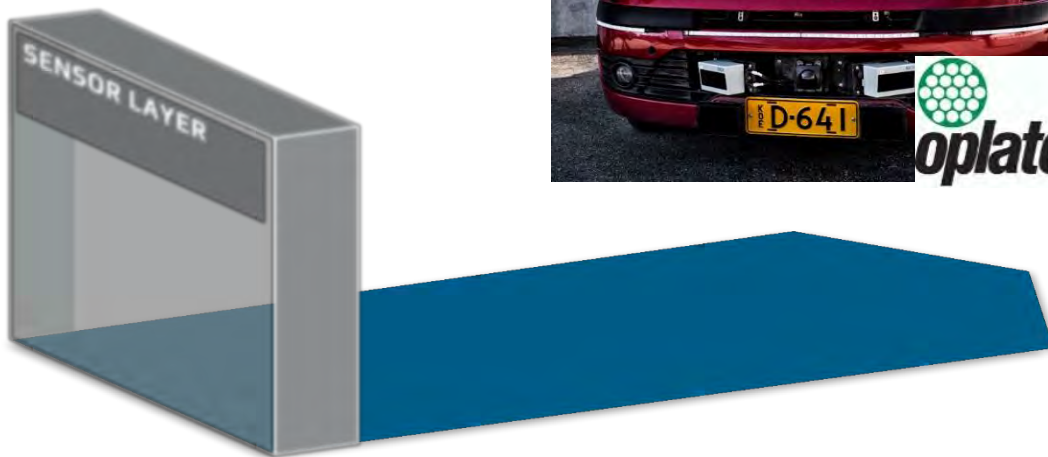
# System performance assessment module



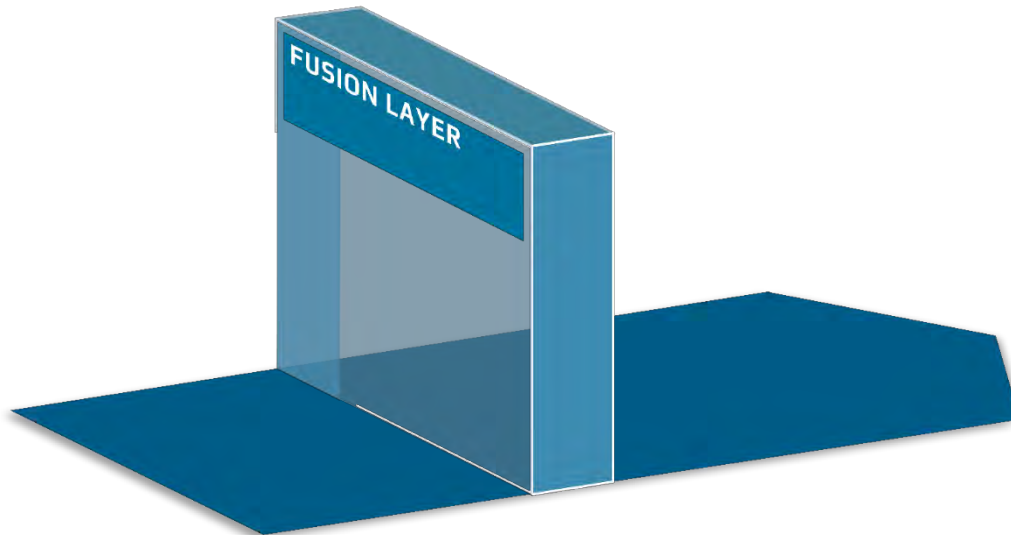
# Integration on test prototypes



**DAIMLER**



# Integration on test prototypes





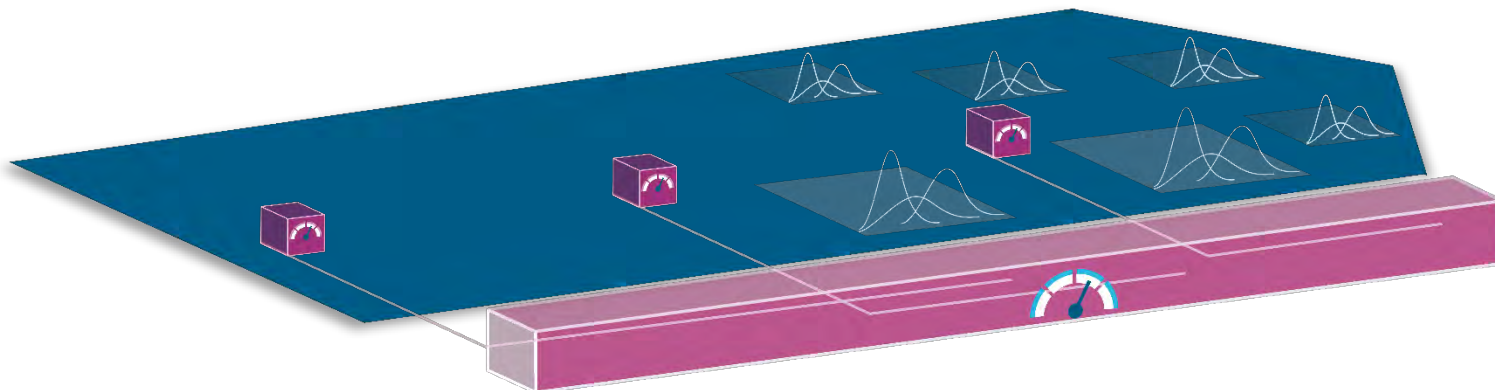
# Integration on test prototypes



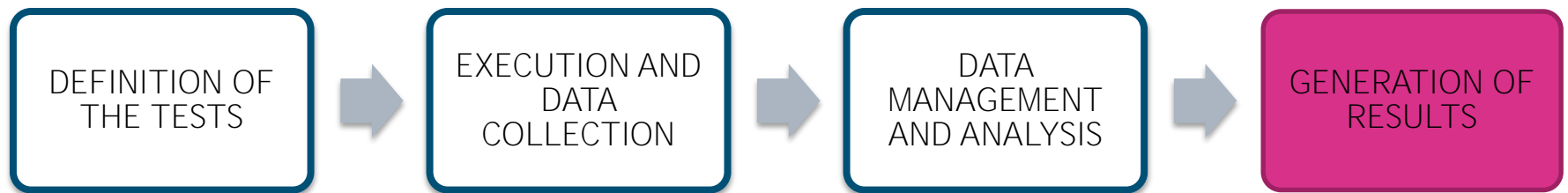
ulm university universität  
**uulm**

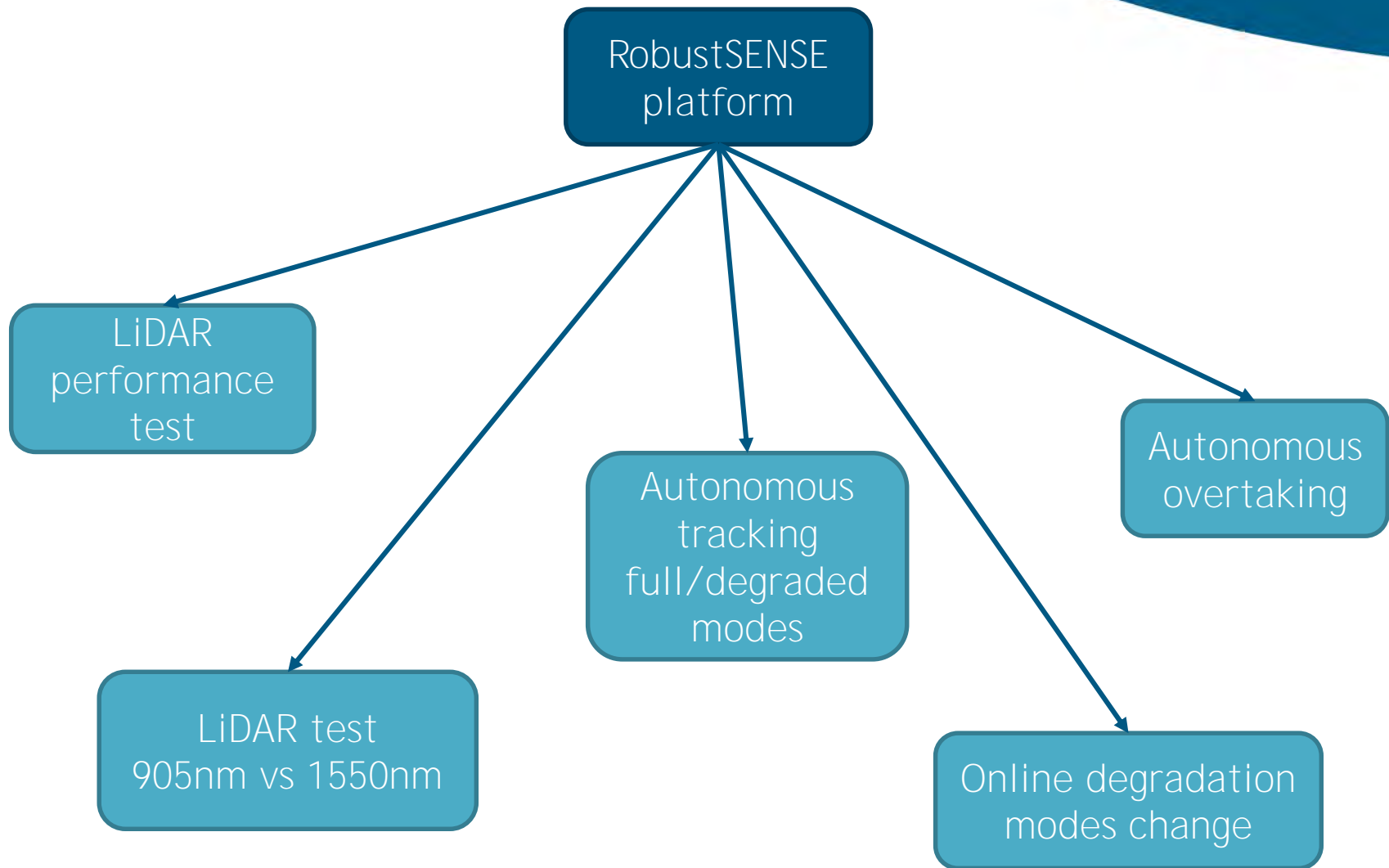


# Integration on test prototypes



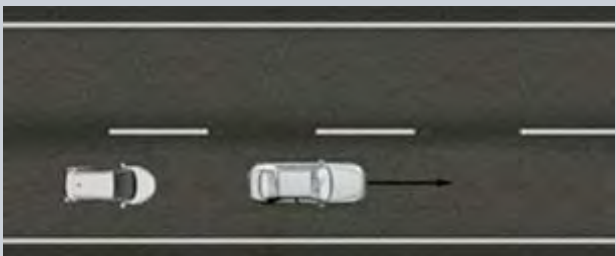






# Test and results

## LiDAR performance test

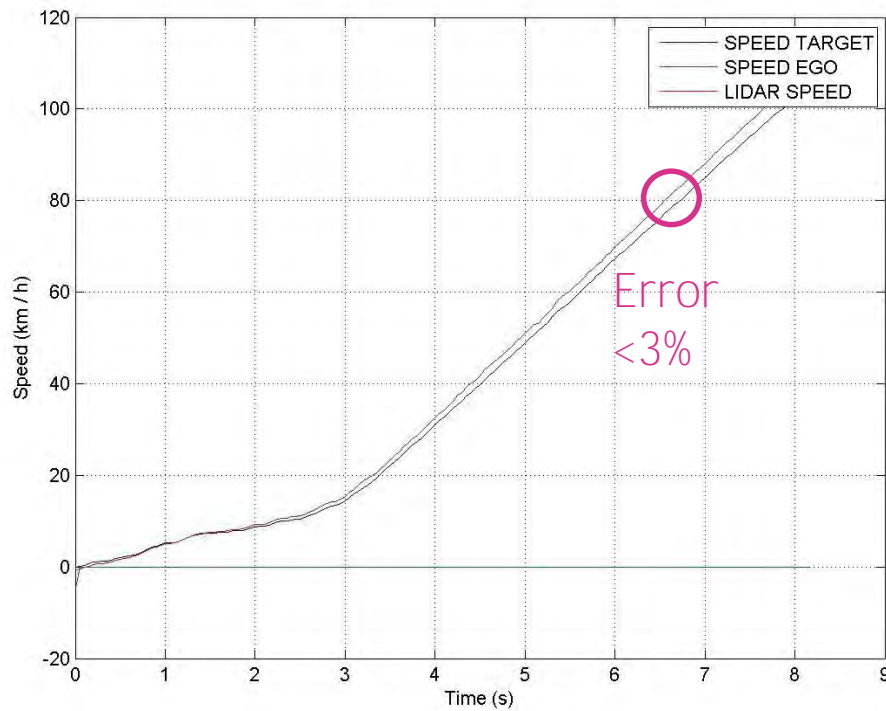
Test Case ID	UC_1_1_TC_1
Test Case Type	LiDAR Test
Testing Methods	Road Testing
Environment	Test Track
Description	The Ego vehicle stands still and the target vehicle begins to accelerate until it is over the distance of 80 meters Target vehicle must be in longitudinal axis all the time without deviation
Objective	Check the length difference among the LiDAR data and dGPS measurements
Development s/modules covered	Sensor layer: LiDAR
Representative Sketch	

Test Setup ID	UC_1_1_TC_1_TS_1
Belongs to Use Case	LiDAR test
Success Criteria	The error in longitudinal distance measured with LiDAR is less than 10% of the longitudinal distance between the ego vehicle and the target vehicle measured with dGPS
Situational Variables	RS_SV-CF-002 (Weather conditions) RS_SV-CF-003 (Road surface condition) RS_SV-CF-004 (Lightning)
Control Factors	RS_SV-CF-005 (Time of day) RS_SV-CF-007 (Road type)
Minimum Set of Metrics and Measures	Ego Vehicle: -dGPS Position -Speed -LiDAR (Perception layer-CAN, WP3): <ul style="list-style-type: none"> <li>• Objects</li> <li>• Type of Object</li> <li>• Relative speed</li> <li>• Relative position</li> </ul> Target Vehicle: -dGPS Position -Speed

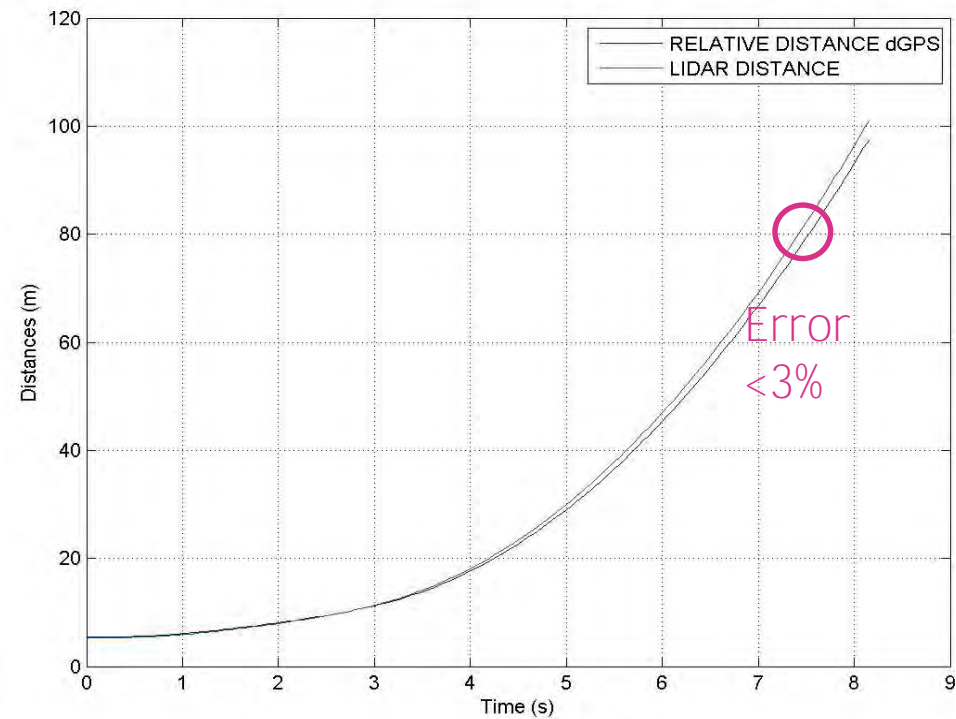
# Test and results

## LiDAR performance test

### Speed

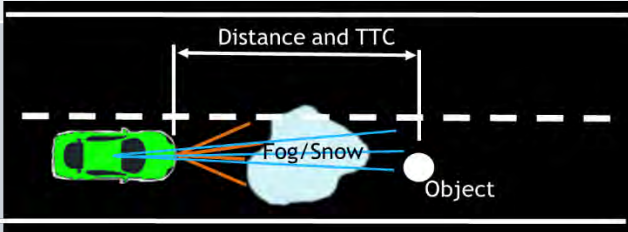


### Distance



# Test and results

## LiDAR test 950nm vs 1550nm

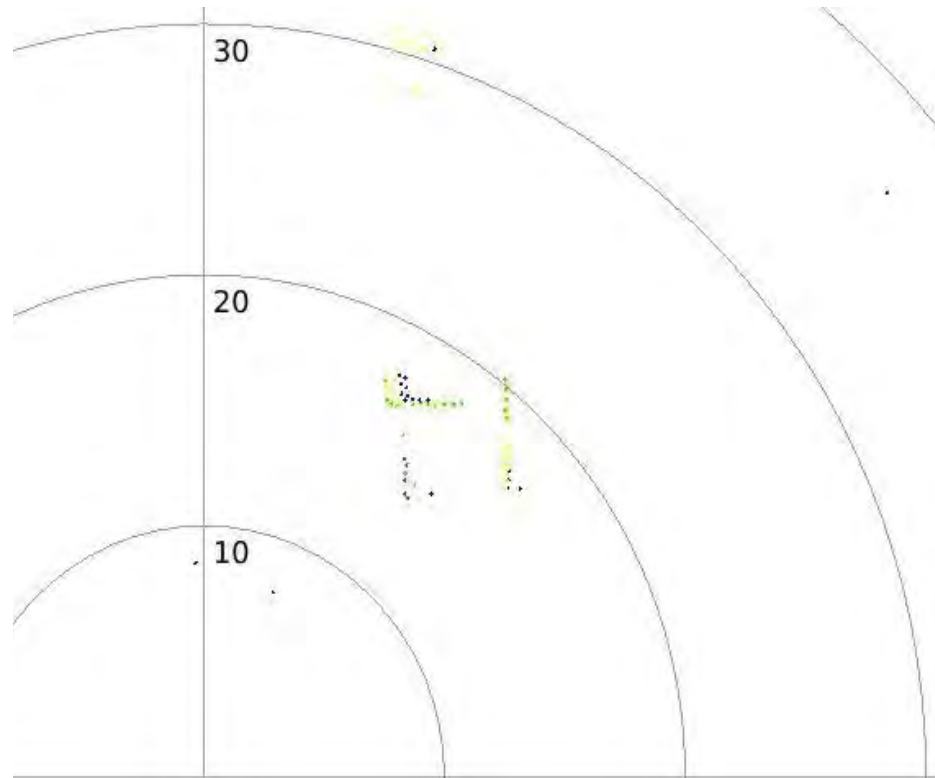
Test Case ID	UC_6_1_TC_1
Test Case Name	ObjectDetection
Test Case Type	LiDAR Test in adverse weather conditions
Testing Methods	Road testing
Environment	Test Track
Description	Stationary testing with producing fog and measure range. The used objects are (metal, pedestrian and plastics)  Adapt automated car function and measure TTC values with and without 1550 nm LiDAR compared to 905 nm LiDAR
Objective:	Estimate improvement for safety margin when using 1550 nm LiDAR
Developments/modules covered:	Sensor layer: LiDAR
Test Setups Summary	UC_6_1_TC_1_TS_1
Representative Sketch:	 <p>The diagram shows a top-down view of a green car on a road with dashed white lines. A blue cloud labeled 'Fog/Snow' is in front of the car. A white circle labeled 'Object' is further ahead. A double-headed arrow above the road indicates the 'Distance and TTC' between the car and the object.</p>

Test Setup ID	UC_6_1_TC_1_TS_1
Belongs to Use Case	ObjectDetection
Success Criteria	Detection distance in fog >30 m time-to-collision with low speed automated car (< 50 km)
Situational Variables	RS_SV-CF-002 (Weather conditions) RS_SV-CF-004 (Lightning)
Control Factors	RS_SV-CF-015 (Fog density)
Minimum Set of Metrics and Measures	<p>Sensor detection range</p> <p>Ego Vehicle:</p> <ul style="list-style-type: none"> <li>-dGPS Position</li> <li>-Speed</li> <li>-LiDAR (Perception layer-CAN, WP3):</li> </ul> <ul style="list-style-type: none"> <li>• <b>Objects</b></li> <li>• Type of Object</li> <li>• Relative speed</li> <li>• Relative position</li> </ul> <p>Targets:</p> <ul style="list-style-type: none"> <li>-dGPS Position</li> <li>-Speed</li> </ul>

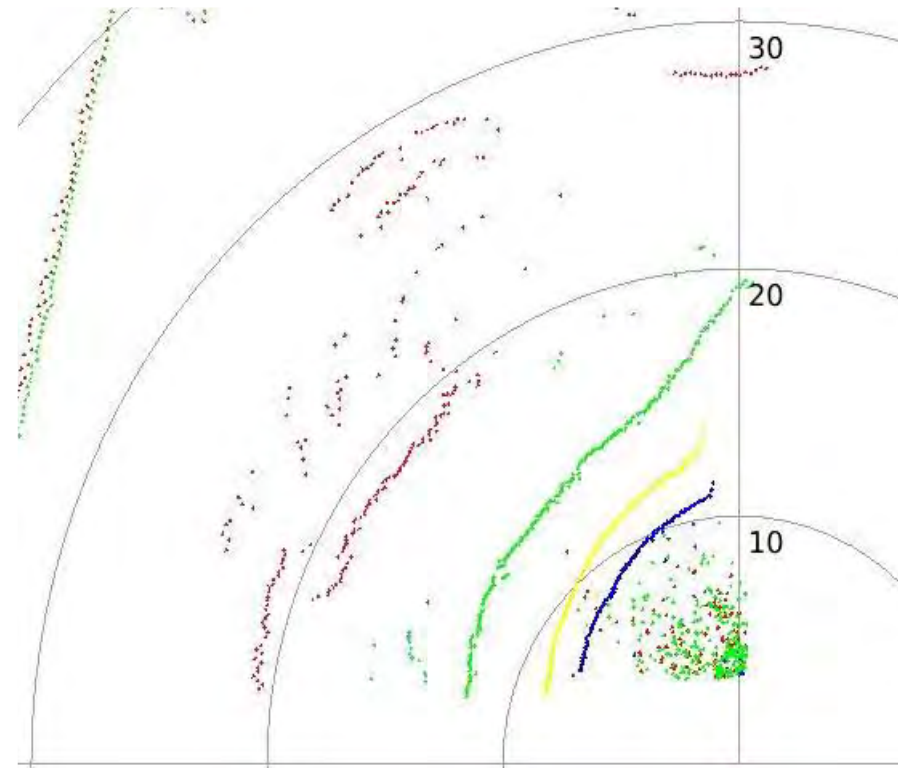
# Test and results

## LiDAR test 905nm vs 1550nm

▼ 1550nm



▼ 905nm

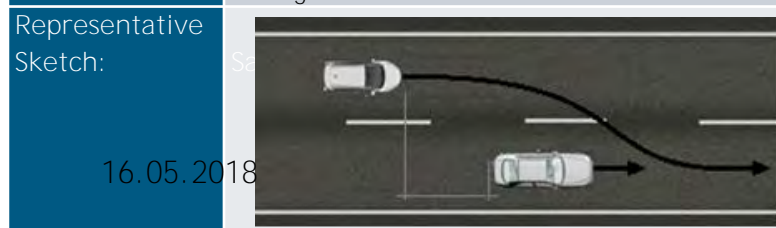




# Test and results

## Autonomous overtaking

Test Case ID	UC_7_2_TC_1
Test Case Name	Overtaking manoeuvre
Test Case Type	Overtaking
Testing Methods	Road Testing
Environment	Test Track
Description	Ego vehicle performs the overtaking of a slower vehicle. Ego vehicle returns to lane 1 when the distance between vehicles is $\Rightarrow$ than the speed-related safety gap, according the specifications.
Objective	Ego vehicle returns to the original lane when the safety gap between vehicles is according the specifications
Developments/ modules covered	Understanding & planning layer: Situation prediction Trajectory planning Sensor layer: LiDAR SPAM layer: Degradation value

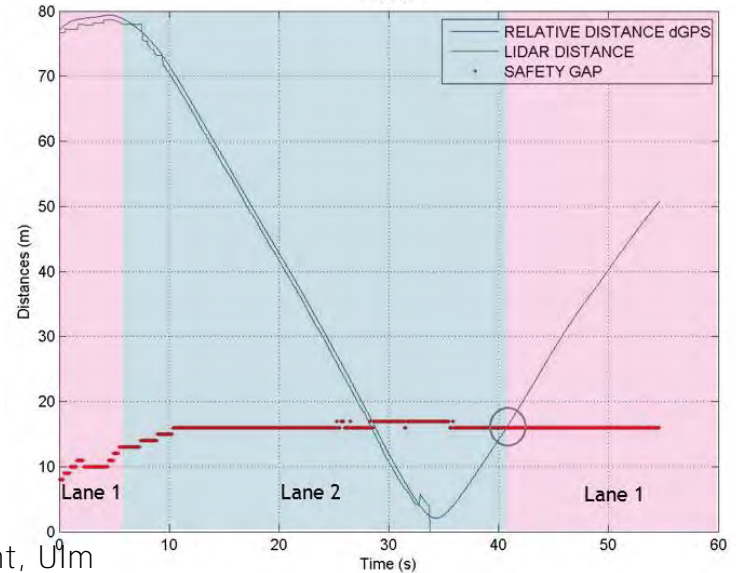
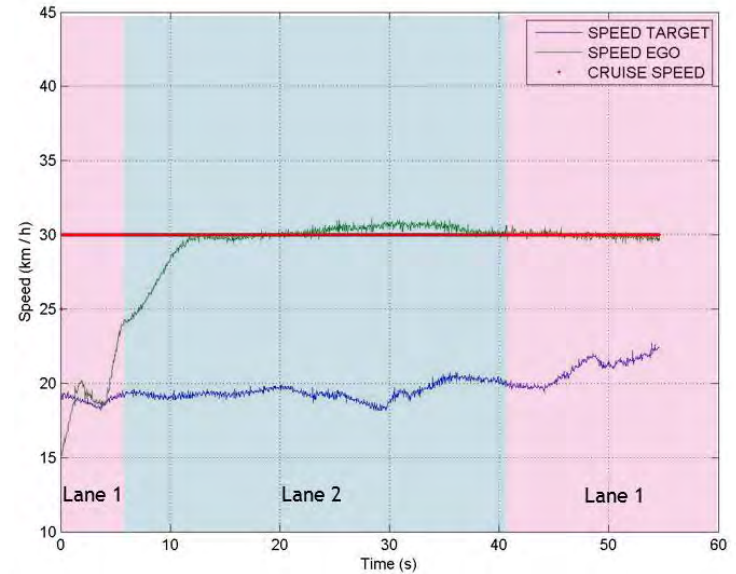
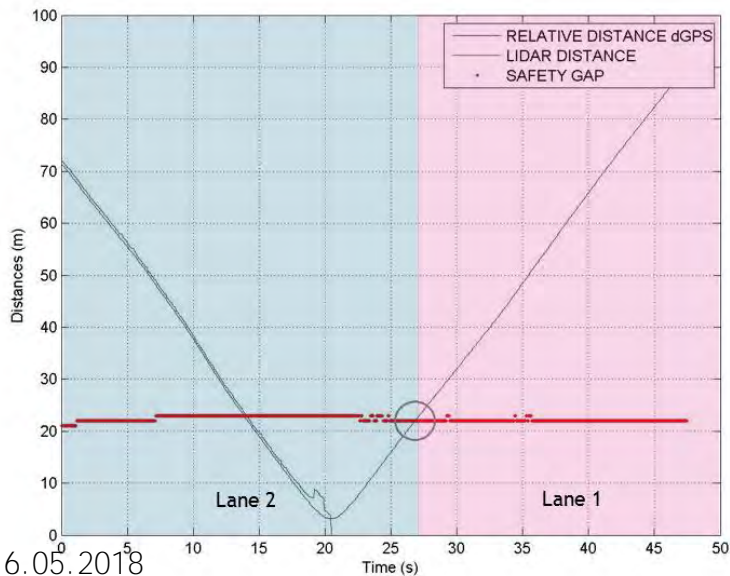
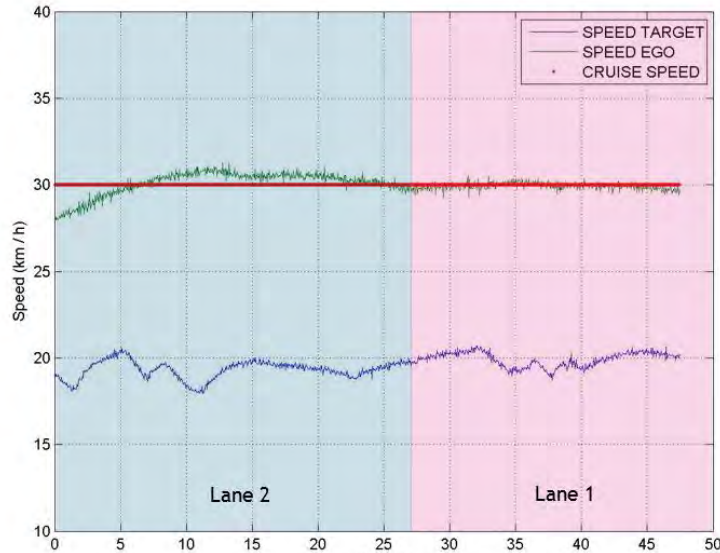


Test Setup ID	UC_7_2_TC_1_TS_1
Belongs to Use Case	Overtaking. Full and degraded modes
Success Criteria	Ego vehicle returns to the original lane after the overtaking keeping the speed-related safety gap according the specifications.
Situational Variables	RS_SV-CF-002 (Weather conditions) RS_SV-CF-003 (Surface condition) RS_SV-CF-004 (Lightning)
Control Factors	RS_SV-CF-005 (Time of day) RS_SV-CF-007 (Road type) <b>RS_SV-CF-008 (Degradation level)</b>
Minimum Set of Metrics and Measures	<p>Ego Vehicle:</p> <ul style="list-style-type: none"> <li>-dGPS Position</li> <li>-Speed</li> <li>-LiDAR (Perception layer-CAN, WP3): <ul style="list-style-type: none"> <li>• <b>Object (vehicle type)</b> <ul style="list-style-type: none"> <li>Speed</li> <li>Position</li> <li>Confidence Value</li> </ul> </li> </ul> </li> <li>-Trajectory planner module (WP4): <ul style="list-style-type: none"> <li>• <b>Longitudinal Prediction Error (SPM3)</b></li> <li>• <b>Lateral Prediction Error (SPM7)</b></li> <li>• <b>Time to Collision Margin (TM2)</b></li> </ul> </li> <li>-SPAM (WP5) <ul style="list-style-type: none"> <li>• <b>Degradation value</b></li> </ul> </li> </ul> <p>Target Vehicle:</p> <ul style="list-style-type: none"> <li>-dGPS Position</li> <li>-Speed</li> </ul>

# Test and results

## Autonomous overtaking


DEGRADED  
MODE



FULL  
MODE

# Test and results

## Autonomous tracking full/degraded modes

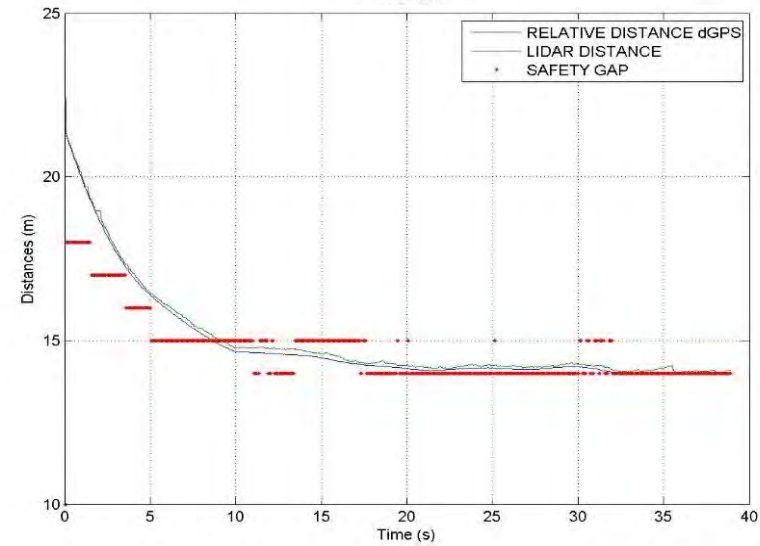
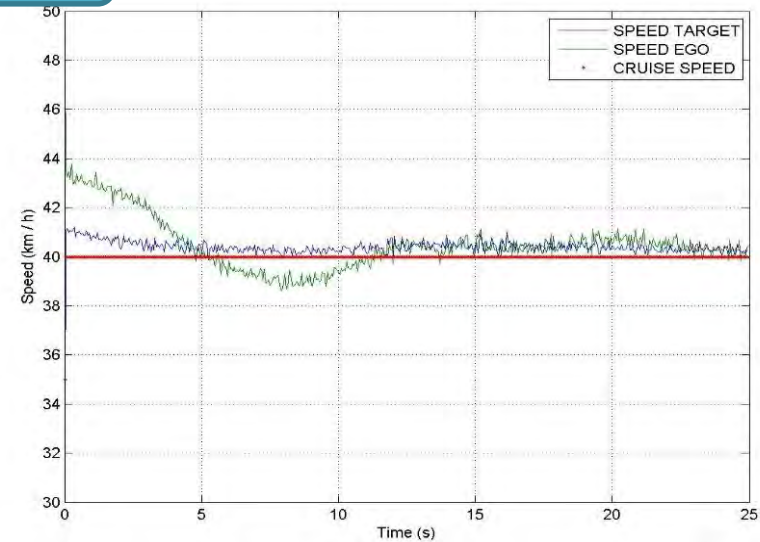
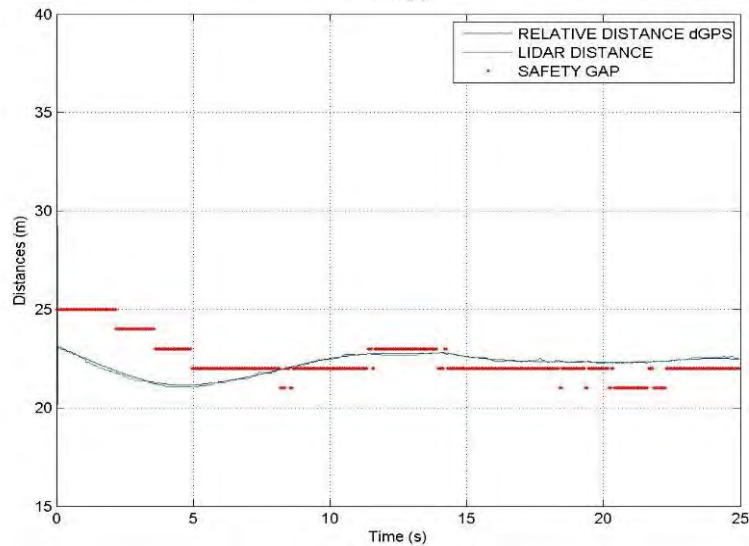
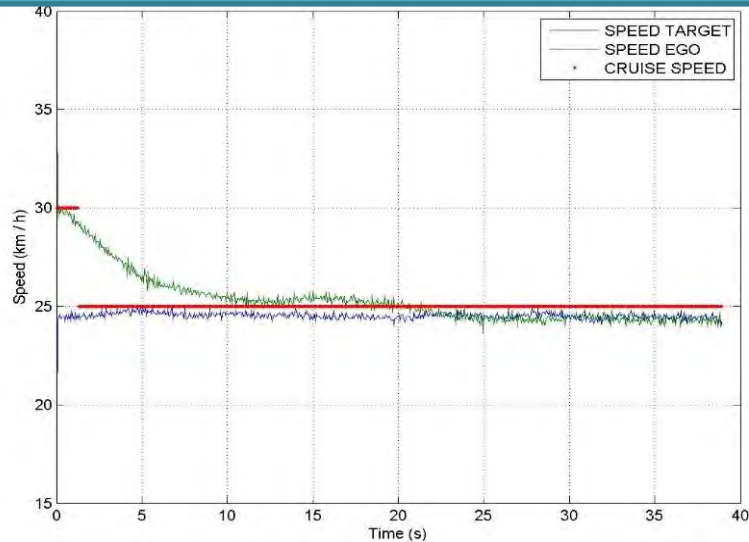
Test Case ID	UC_7_1_TC_1
Test Case Name	Ego vehicle follows target vehicle at constant speed
Test Case Type	Vehicle tracking
Testing Methods	Road Testing
Environment	Test Track
Description	Ego vehicle follows a target vehicle with constant speed in straight line. Ego vehicle adjusts automatically cruise speed to target vehicle speed. Keep this situation until the objective speed-related safety gap is reached.
Objective	Ego vehicle follows target vehicle, reaching and keeping the speed-related defined safety gap in the active mode (full/degraded)
Developments/modules covered	Understanding & planning layer: Situation prediction Safe trajectory planning Sensor layer: LiDAR
Representative Sketch	

Test Setup ID	UC_7_1_TC_1_TS_1
Belongs to Use Case	Vehicle tracking
Success Criteria	The safety gap between the ego and target vehicles does not deviate from the specifications in full mode at the tested speeds
Test Setups Summary	TS 7.1.1.1.A TS 7.1.1.1.B
Situational Variables	RS_SV-CF-002 RS_SV-CF-003
Control Factors	RS_SV-CF-005 RS_SV-CF-007
Minimum Set of Metrics and Measures	Ego Vehicle: -dGPS Position & Speed -LiDAR (Perception layer-CAN, WP3): • <b>Object (vehicle type)</b> Relative speed & position Confidence Value -Trajectory planner module (WP4): • Longl Prediction Error (SPM3) • Lat Prediction Error (SPM7) -SPAM (WP5) • <b>Degradation value</b> Target Vehicle: -dGPS Position & Speed
Sensors and data loggers	CTAG Datalogger LiDAR

# Test and results

## Autonomous tracking full/degraded modes

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E



# Test and results

## Online degradation modes change

Test Case ID	UC_7_1_TC_2
Test Case Name	Vehicle tracking. Modes switching Case
Test Case Type	Vehicle tracking
Testing Methods	Road Testing
Environment	Test Track
Description	When the safety gap reached corresponds to the specifications, the full mode is switched manually to the degraded mode and reverse. Vehicle should adapt speed-related safety gap according the active mode.
Objective	The ego vehicle adjusts the speed-related safety gap according to the active driving mode.
Developments/modules covered	Understanding & planning layer: Situation prediction Trajectory planning Sensor layer: LiDAR
Representative Sketch	

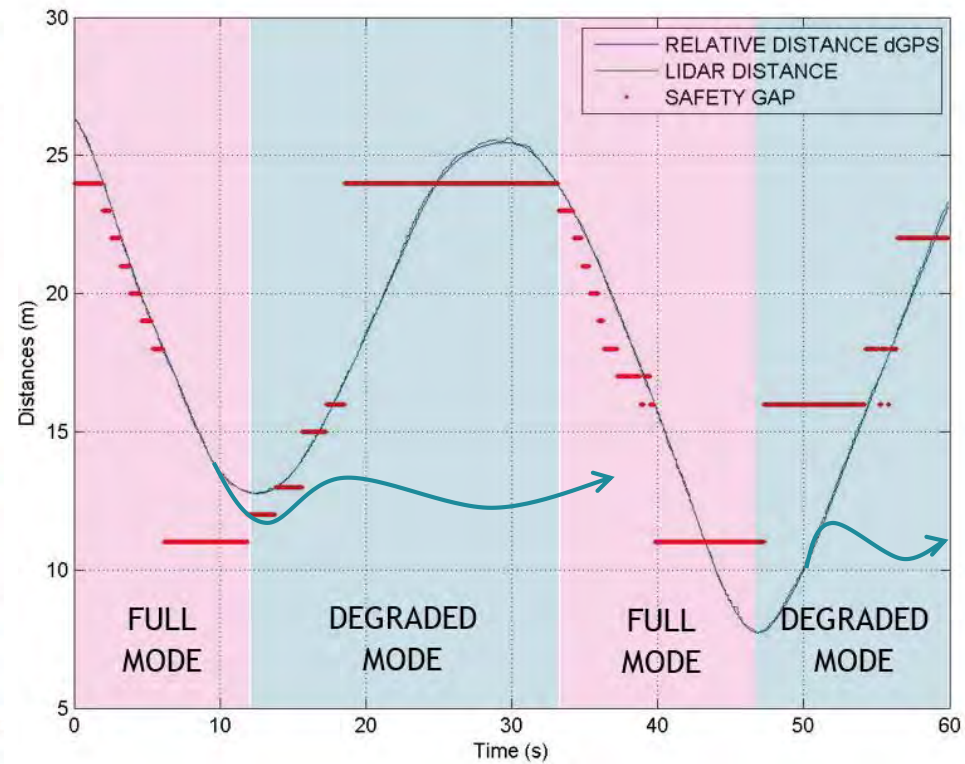
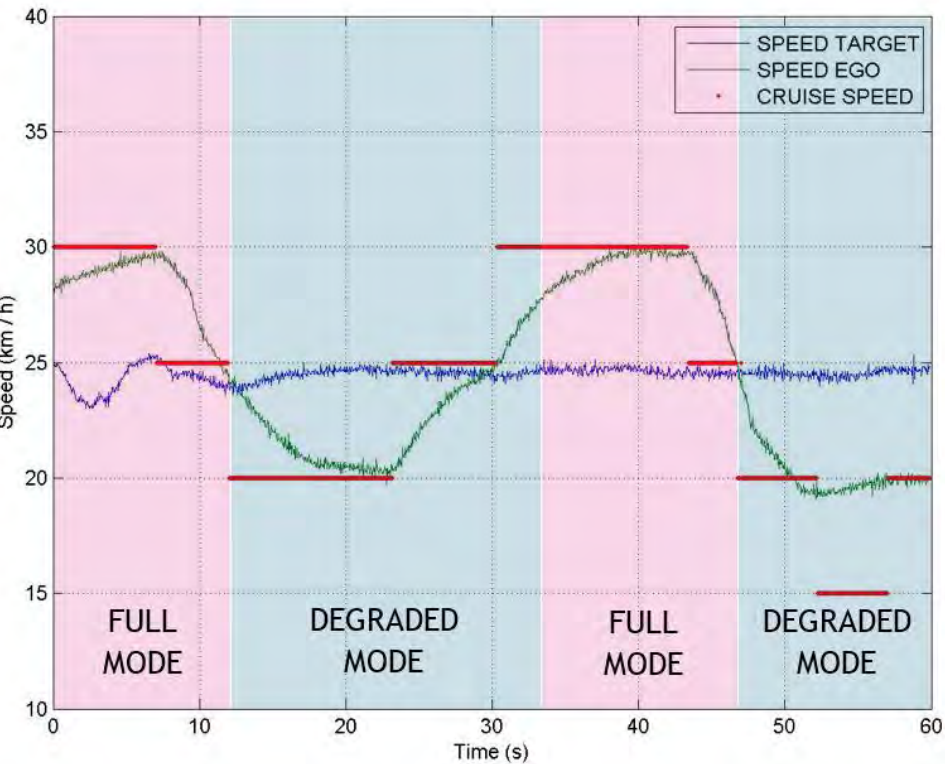
16.05.2018

Test Setup ID	UC_7_1_TC_2_TS_1
Belongs to Use Case	Vehicle tracking
Success Criteria	The ego vehicle adjusts the safety gap according to the active driving mode
Situational Variables	RS_SV-CF-002 RS_SV-CF-003 RS_SV-CF-004
Control Factors	RS_SV-CF-005 RS_SV-CF-007 RS_SV-CF-008
Minimum Set of Metrics and Measures	<p>Ego Vehicle:</p> <ul style="list-style-type: none"> <li>-dGPS Position &amp; Speed</li> <li>-LiDAR (Perception layer-CAN, WP3): <ul style="list-style-type: none"> <li>• <b>Object (vehicle type)</b> <ul style="list-style-type: none"> <li>Speed &amp; Position</li> <li>Confidence Value</li> </ul> </li> </ul> </li> <li>-Trajectory planner module (WP4): <ul style="list-style-type: none"> <li>• Long Prediction Error (SPM3)</li> <li>• Lat Prediction Error (SPM7)</li> <li>• <b>Time to Collision Margin (TM2)</b></li> </ul> </li> <li>-SPAM (WP5) <ul style="list-style-type: none"> <li>• <b>Degradation value</b></li> </ul> </li> </ul> <p>Target Vehicle:</p> <ul style="list-style-type: none"> <li>-dGPS Position &amp; Speed</li> </ul>
Sensors and data loggers	CTAG Datalogger LiDAR

Final Event, Sim

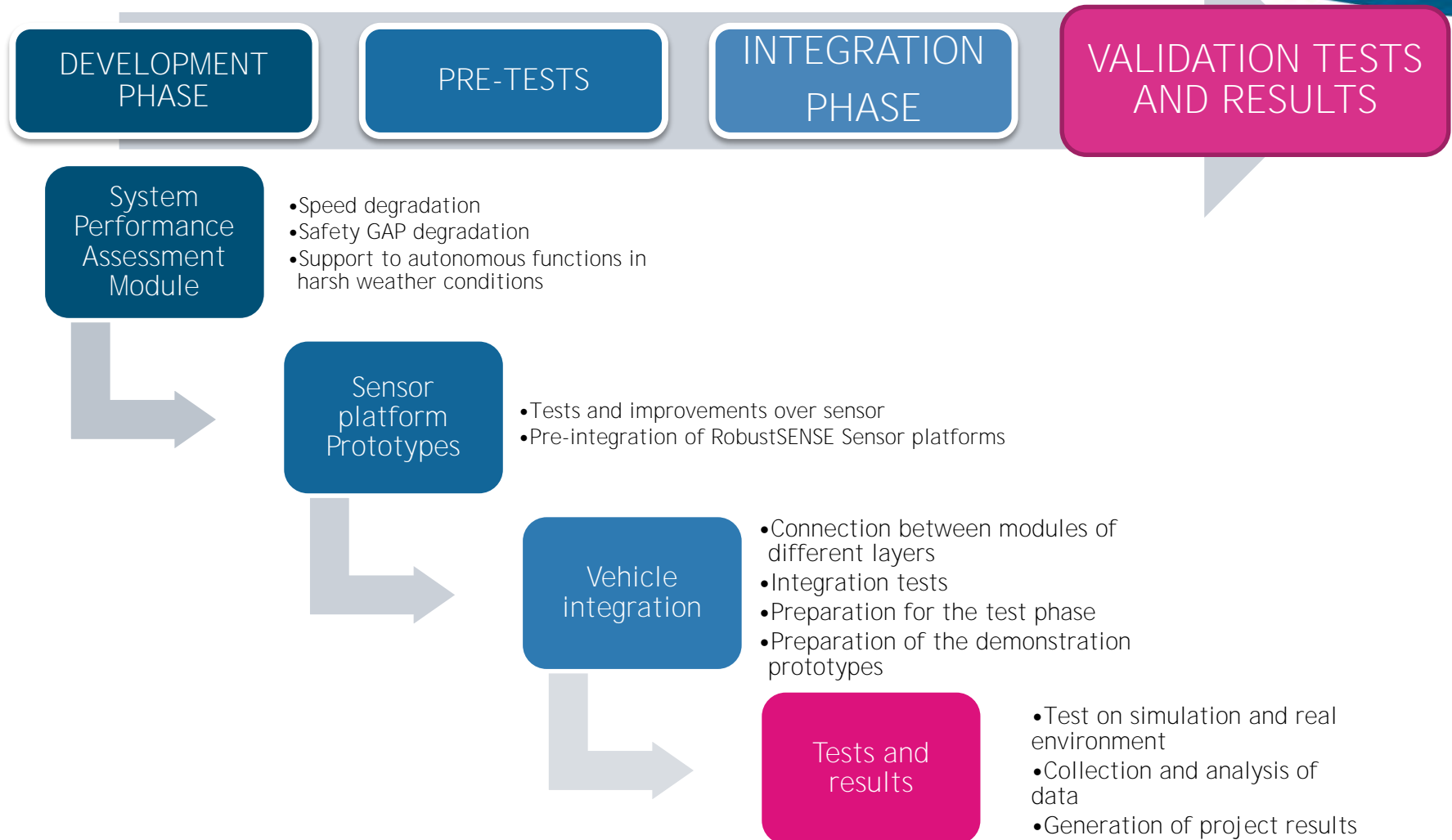
# Test and results

Online degradation modes change

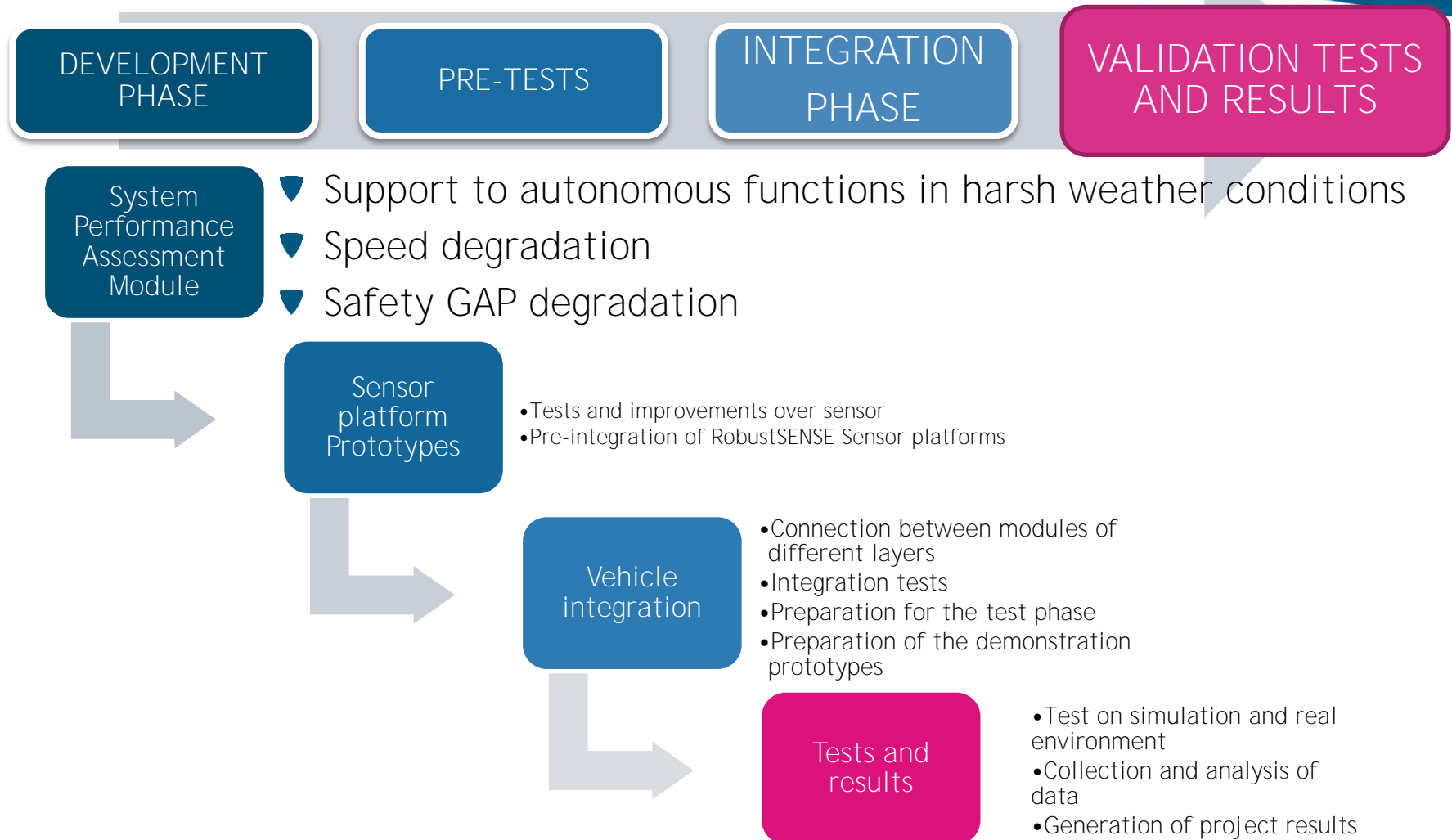




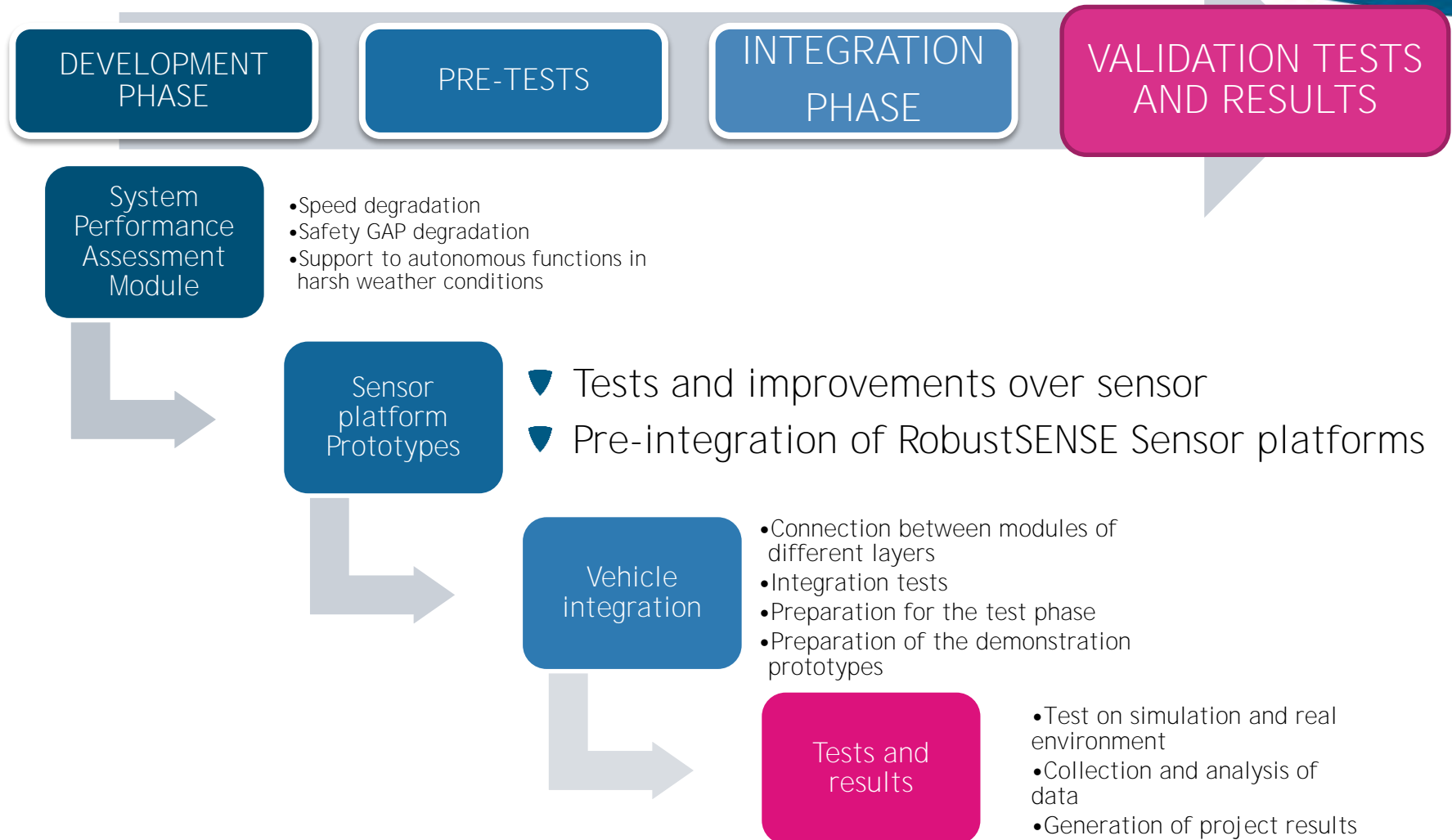
# Summary of progress



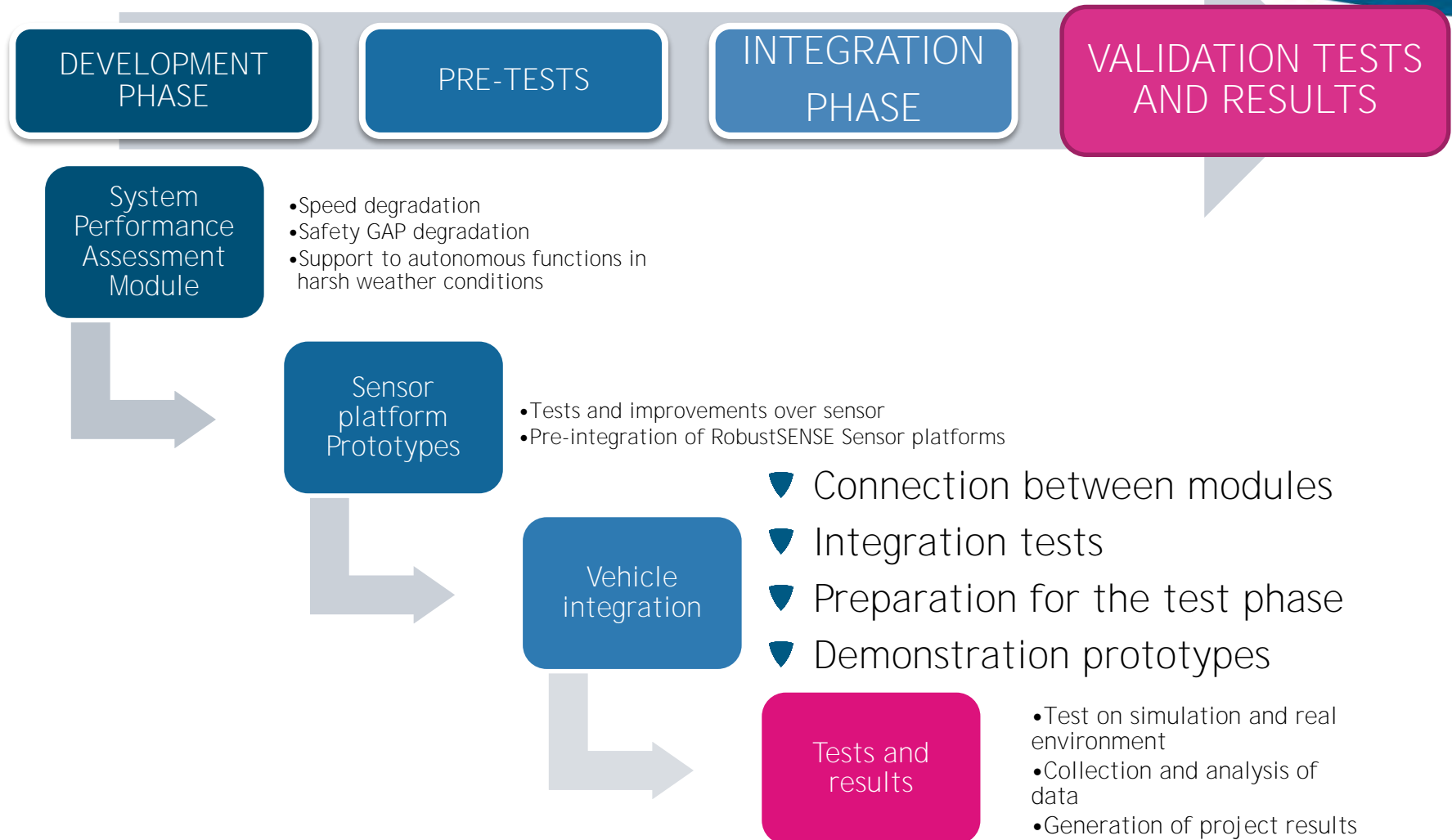
# Summary of progress



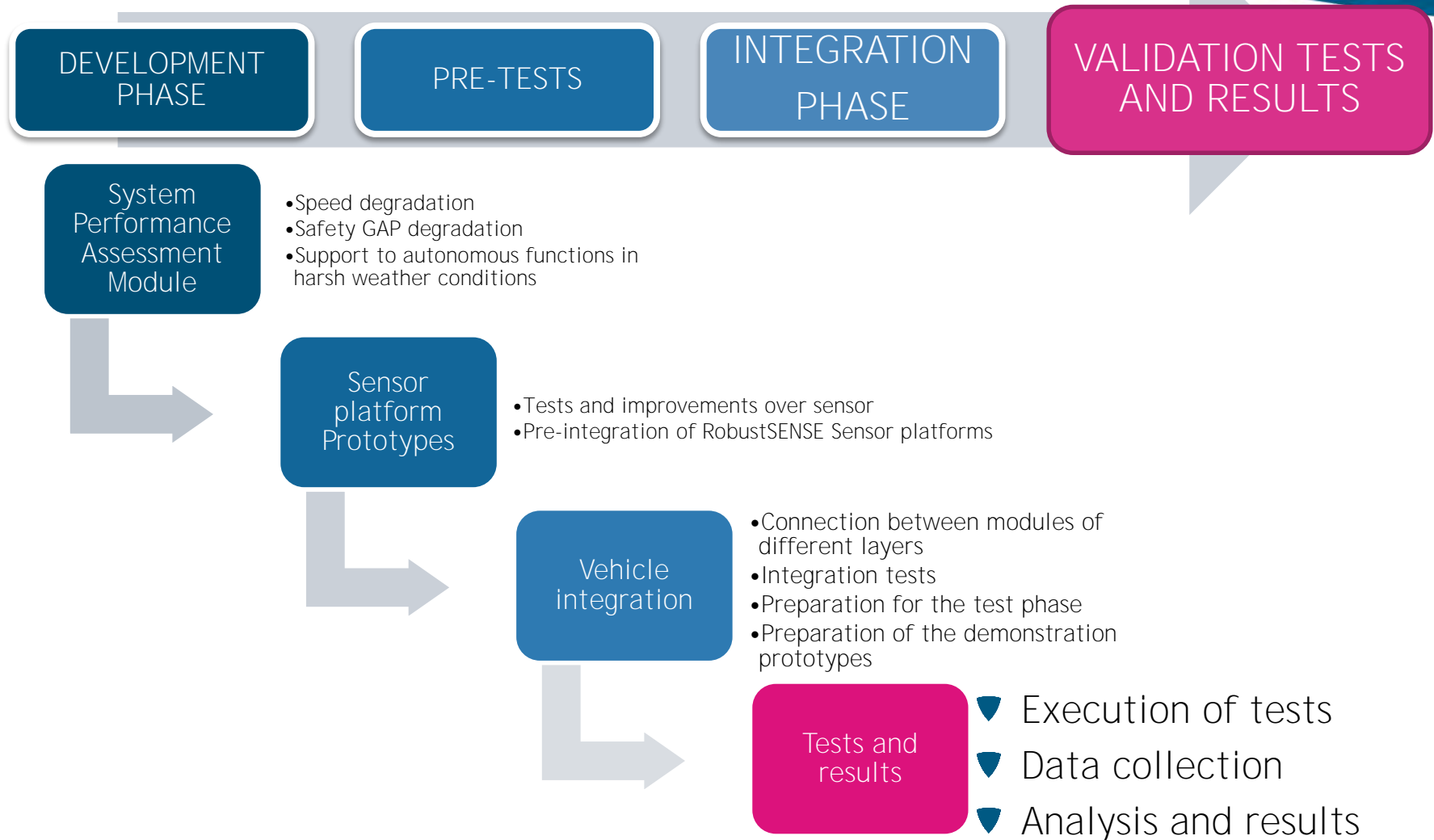
# Summary of progress



# Summary of progress



# Summary of progress





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Thank you.



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the European Union

