Current State-of-the-Art In Indirect TPMS

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Outline

- Introduction
- Indirect TPMS basics
- NIRA Dynamics TPI
  - Functionality
  - Performance
  - Integration in the vehicle
- Processes and tools for online and offline functional tests
- Ideas for improved quality and efficiency of test and verification work
- TPMS market situation USA and EU

Introduction

NIRA Dynamics AB…

- …is a privately owned company based in Sweden.
- …has expertise in signal processing and software development.
- …focuses on vehicle dynamics and active safety applications.
- …develops, markets, and sells in-house developed software products.
- …offers advanced indirect TPMSs for different applications:

TPI state-of-the-art indirect TPMS capable of detecting under-inflation in 1−4 tires and meeting the requirements of FMVSS 138

Safety Aspects of TPMS

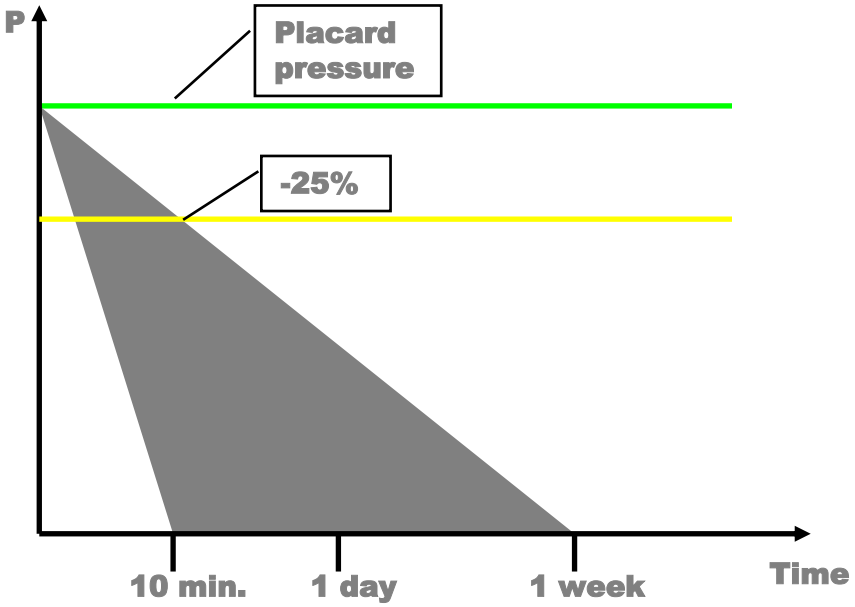
- TPMSs will not prevent 100% of the accidents caused by tire issues.
- A TPMS monitors the tire pressures and can alert the driver of potentially dangerous under-inflation scenarios.
- The driver is always responsible for maintaining correct inflation pressure(s) in the tires.
- TPMSs should be devloped considering real-world pressure drop scenarios.

Nominal

-30%

TPMS Requirements in Real-World Pressure Drop Scenarios

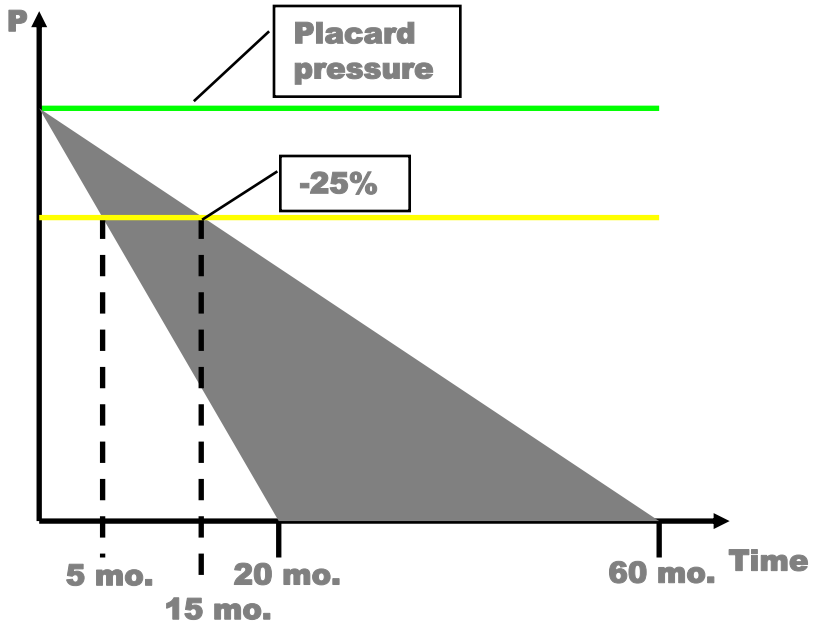
Punctures



Main requirement: quick warning

(Non-requirement: warning threshold)

Natural Leakage – Diffusion



Main requirement: monitoring of all four tires

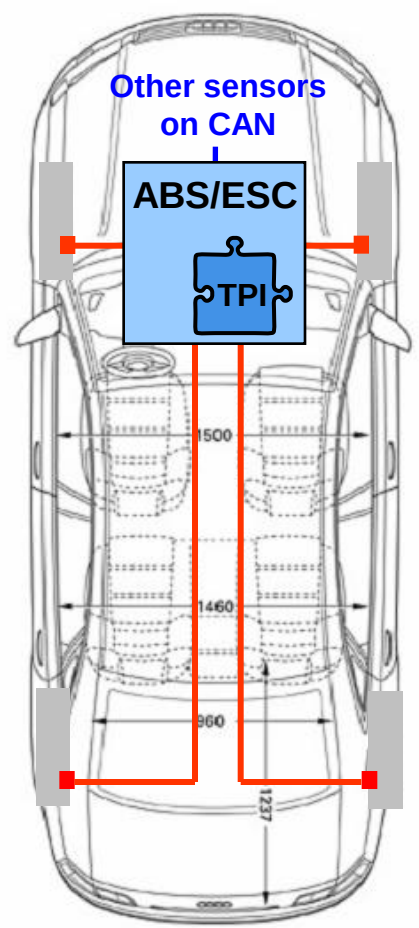
(Non-requirement: detection time)

Operating Principles of Indirect TPMSs

Indirect TPMSs…

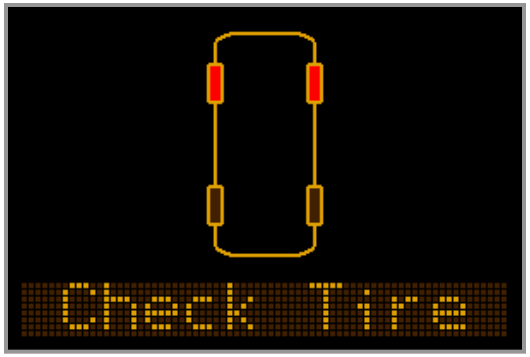
- are software-based systems, not requiring any pressure sensors mounted inside the tires.
- use data from already available sensors in the vehicle: wheel speed sensors, yaw rate gyros etc.
- compute pressure-related parameters and issue warnings when current and calibrated parameter values differ enough.

Initial learning of the nominal tire characteristics (calibration) is required.



NIRA Dynamics TPI

- Detects under-inflation of -25% in 1-4 tires.
- Meets the requirements of FMVSS 138.
- Identifies the under-inflated tire(s).
- Is designed for passenger cars, light trucks and SUVs.
- Works with different types of tires including summer, winter and all-season tires, low profile tires and run-flat tires.
- Is robust against nuisance warnings due to load changes, aggressive driving and other factors.



Example warning display

TPI featured in several Audi models

TPI Test Results, Example 1: 2 Tires, -25%

Test Information

Purpose:
2 tire deflation

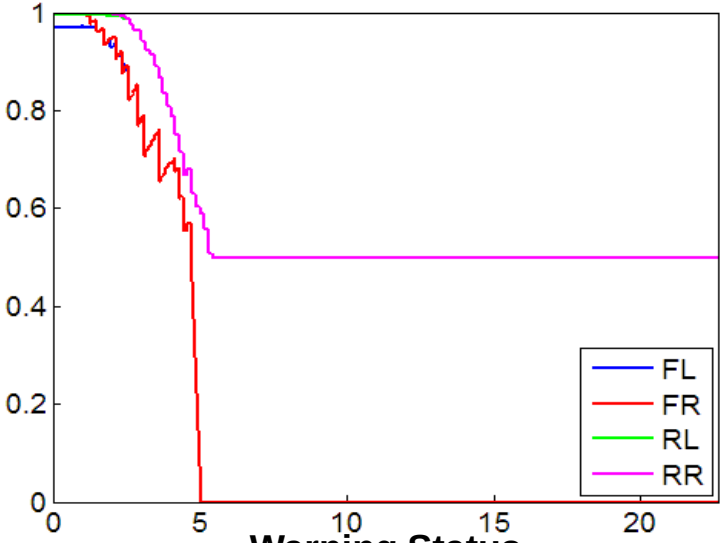
Road surface:
Asphalt

Vehicle:
Audi A6 3.2 FSI FWD

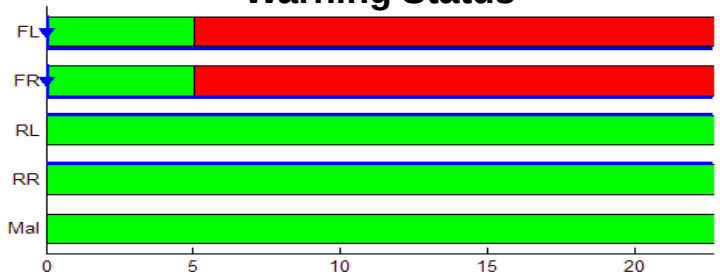
Tires:
Bridgestone Potenza 255/40-R18

Pressures (kPa):
FL: 230 -> 173
FR: 230 -> 173
RL: 270
RR: 270

Pressure Indicators



Warning Status



TPI Test Results, Example 2: 4 Tires, -25%

Test Information

Purpose:
4 tire deflation

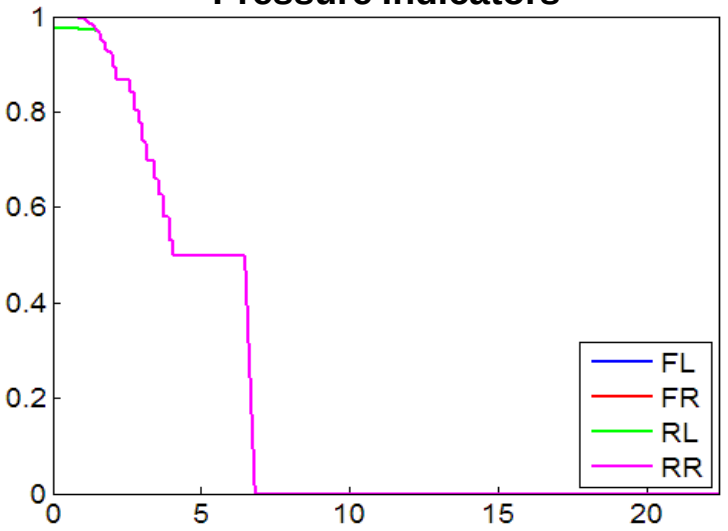
Road surface:
Asphalt

Vehicle:
Audi A6 3.2 FSI FWD

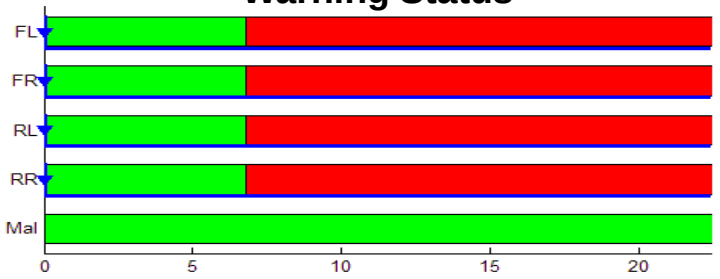
Tires:
Bridgestone Potenza 255/40-R18

Pressures (kPa):
FL: 230 -> 173
FR: 230 -> 173
RL: 270 -> 203
RR: 270 -> 203

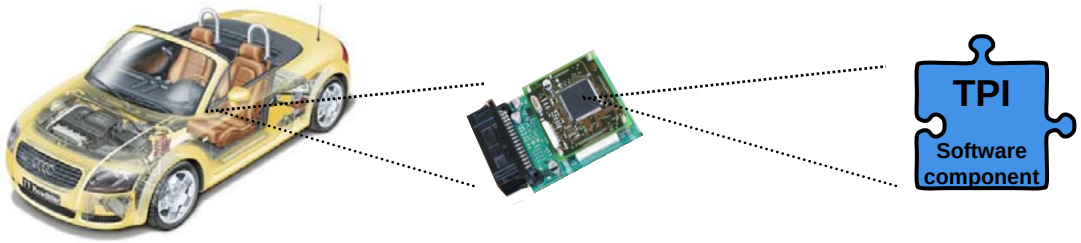
Pressure Indicators



Warning Status

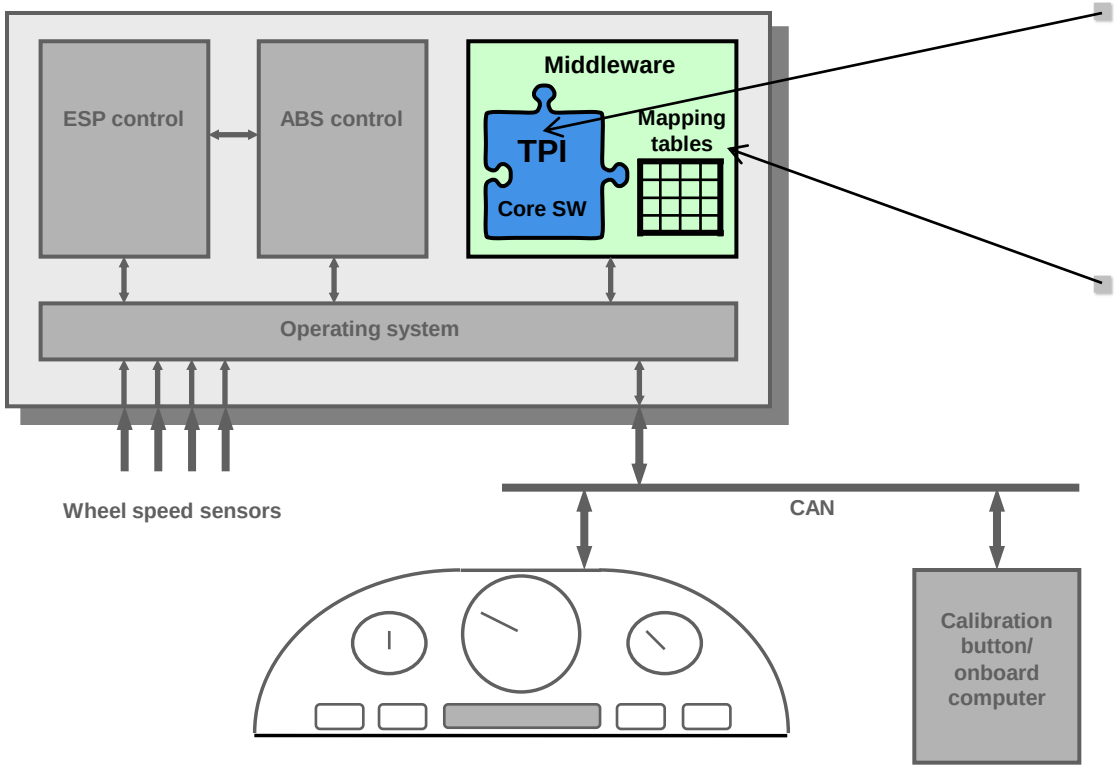


TPI Integration In The Vehicle



- TPI uses only existing sensors in the vehicle and does not require any extra hardware
- TPI is delivered as a standardized software component and can be integrated as is in different target systems such as:
  - ABS/ESC ECU
  - Airbag ECU
  - Chassis/Body ECU
- The TPI software is delivered as a standardized software component compiled for the chosen target processor
- The TPI function is accessed through a well-defined, easy-to-use, public API
- The API controls the signal flow and execution of the TPI software

System Architecture



TPI core software

- Implemented in ANSI C code
- Delivered as binary file
- Realizes the TPI function and the API

Middleware

- Implemented by the system supplier/integrator
- Manages
  - TPI execution control
  - I/O handling
  - EEPROM handling
  - Diagnostics
- Includes application specific mapping tables

Development Challenges

- Fulfill the relevant legislations and regulations (FMVSS 138)
- Satisfy customer requirements (no warranty costs)
  - Detection sensitivity and consistency
  - Robustness against nuisance warnings
  - Minimum service effort and defects
  - Easy operation
- Minimize costs
  - Development cost per vehicle application/program
  - (Production cost per vehicle)

Vehicle Tests

Development of an indirect TPMS (application) requires data from real-world vehicle tests:

- Different engine and powertrain configurations
- Different tires
- Different load conditions
- Different driving scenarios
- Etc, etc

Development time and costs can increase very quickly if brute force approach to vehicle testing is taken…

Key Observation: TPI Open-Loop System

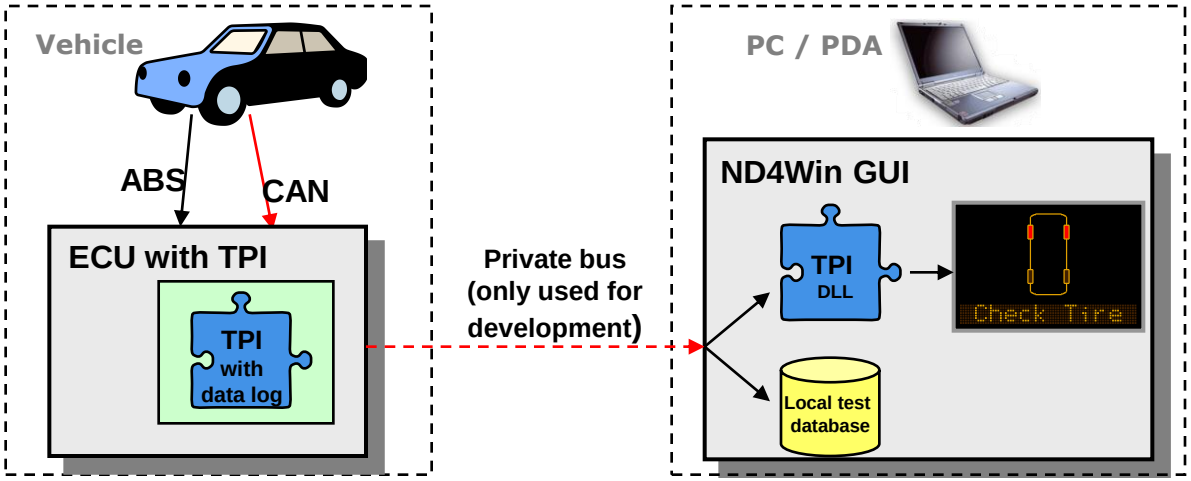
Can re-use old test data and test

- new algorithms and software,
- new parameter settings, and
- new requirement specifications

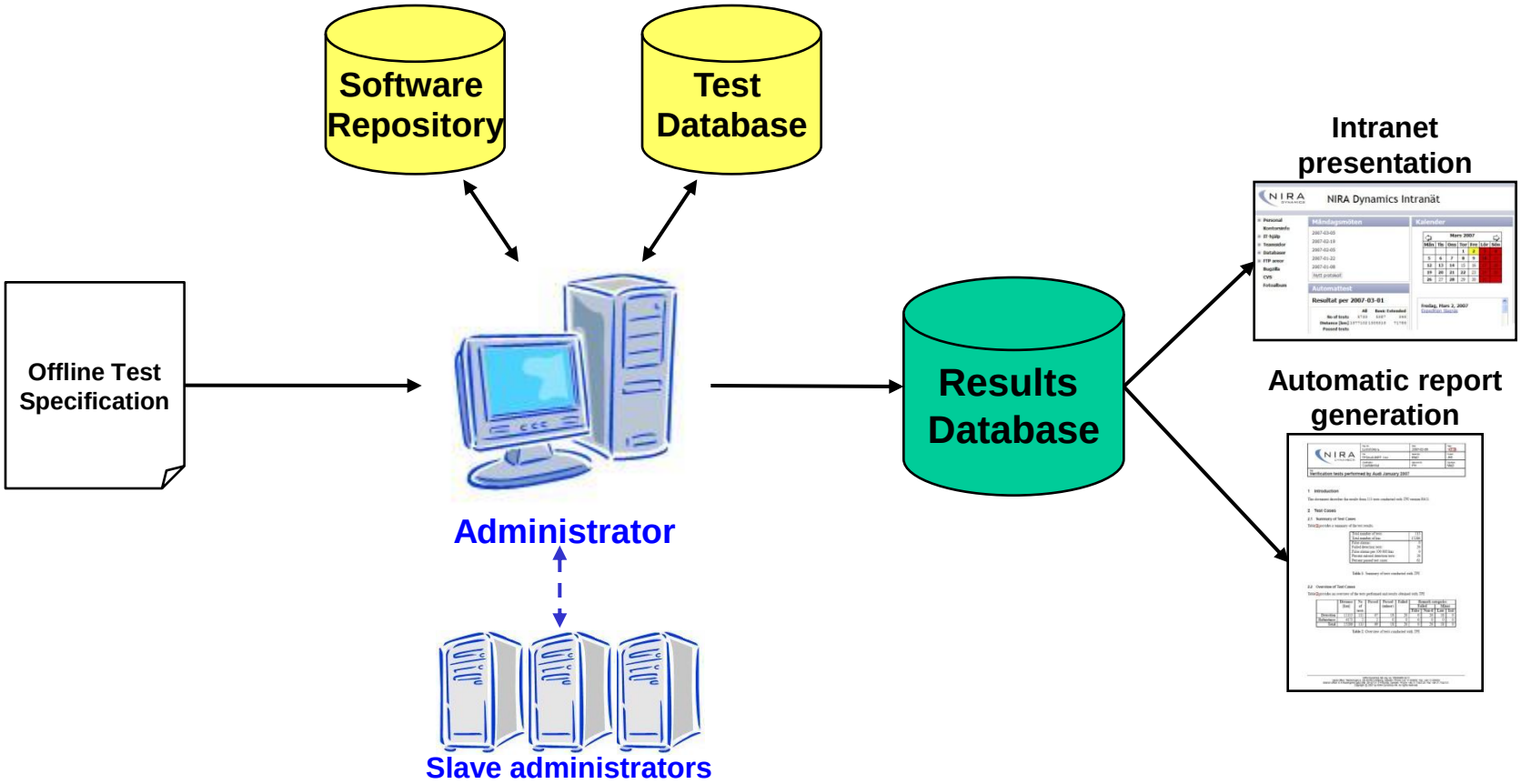
offline without repeating online (vehicle) tests!

Online Test and Datalogging Tools

- The TPI software core has a built-in data logging feature
- Supports parallel execution of product code on PC and target plus simultaneous data logging and storage in local test database



Offline Test Environment



Other Ideas for Cost Control

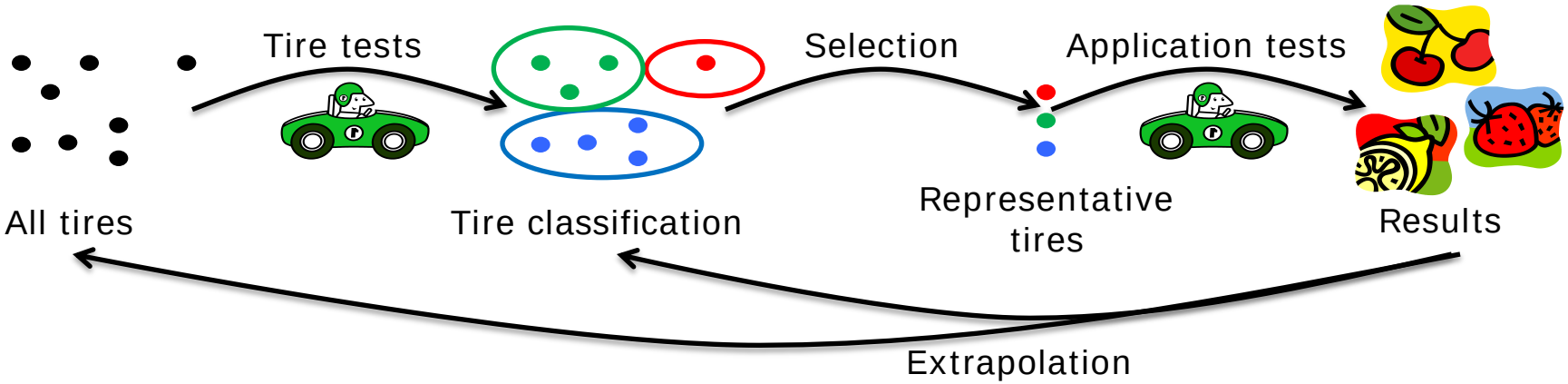
- Vehicle screening
- Tire screening
- Tire classification using rig test data

Vehicle Screening

- Idea and purpose:
  - Complete a short, standardized test program in many different vehicles of a certain model to learn as much as possible about the characteristics of the vehicle model in question without having to go through full test programs for more than a few test vehicles.
- Benefits:
  - Saves time and cost.
  - Standardized test program allows cross-comparisons between different models.
  - If applied also to used vehicles it will allow analysis of ageing and wear effects.

Tire Screening

- Idea and purpose:

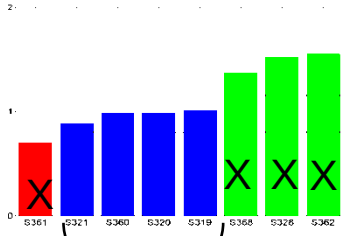


- Benefits:
  - Saves time and cost.
  - Standardized test program allows efficient analysis of tire properties and cross-comparisons between different vehicle models.

Tire Classification Project

Purpose and goal:

- Preselection of tires based on rig-test results.
- Use selected tires for application work on vehicle.



= Time and cost reduction

Vehicle tests

Project Overview

Project partners:

NIRA DYNAMICS, Audi, BMW, Bridgestone, Dunlop

Basic job split:

- Vehicle tests @ AUDI & BMW
- Rig tests @ Bridgestone
- Rig tests @ Dunlop

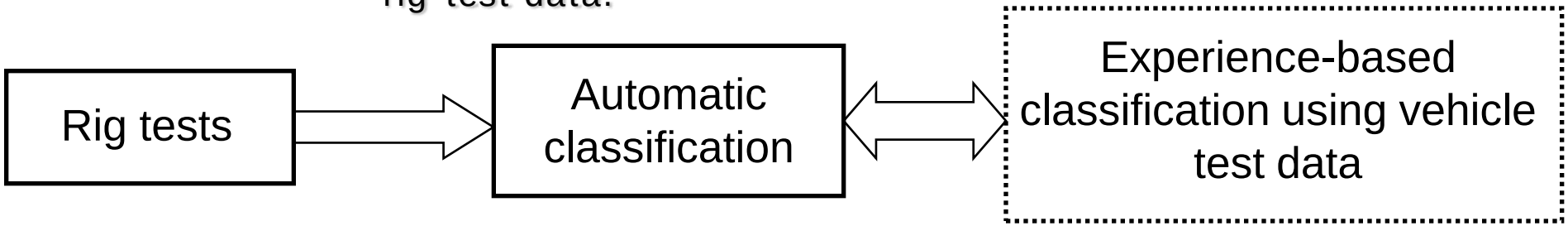
→ Data analysis @ NIRA Dynamics

Method

Background: experience-based classification of tires based on vehicle test data:

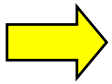
Insensitive | Medium | Sensitive

Ongoing work: find a robust automated and objective analysis tool based on rig-test data.



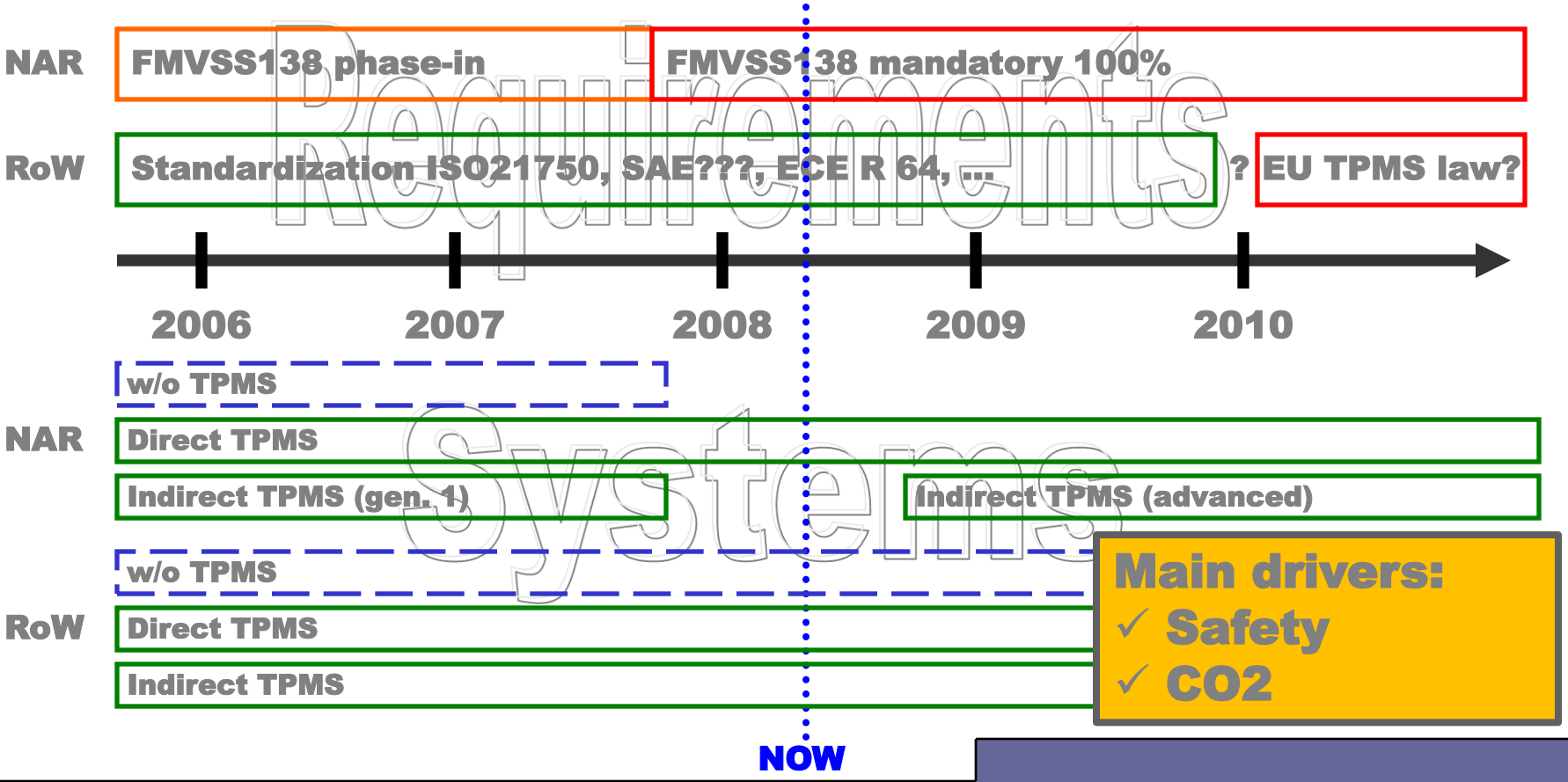
Summary and Conclusions

- Development focus for advanced indirect TPMS has shifted from research and pre-development to efficiency and optimization issues by now
- Vehicle tests still important but focused and purposeful vehicle tests combined with extensive use of offline testing will lead to dramatically reduced application times and costs!



Advanced indirect TPMS will become even more competitive, also for low volume programs!

TPMS Market Situation - Now and Near Future



Thank you for your attention!