Framework for Virtual and Physical Testing of Automated Driving Systems

Vladislav Kocián, Jiří Svoboda

Highly Automated Driving
TÜV SÜD Czech

MathWorks
AUTOMOTIVE CONFERENCE 2020
EUROPE

VLADISLAV KOCIÁN

TÜV SÜD at a glance

150+
YEARS OF SAFETY, SECURITY & SUSTAINABILITY

1,000+
LOCATIONS WORLDWIDE

€2.5
BILLION IN ANNUAL REVENUE

24,500+
EMPLOYEES*

41%
OF REVENUE OUTSIDE GERMANY^

574,000
CERTIFICATES

100%
INDEPENDENT & IMPARTIAL

1-STOP
SOLUTIONS PROVIDER

*As of 2018-12-31
^Based on clients‘ locations
Note: Figures have been rounded off.

AB Dynamics SR15 ORBIT
TÜV SÜD
14:22
Úterý, 01.10.2019
53 km/h
KIA
50.55
2394.13
27
40.03
-0.09

Evolution of automated driving systems

Level 1

DRIVER ASSISTANCE
- Adaptive Cruise Control
- Parking Assistant
- AEB

Level 2

PARTLY AUTOMATED
- ACC & LKA
- Park Asist

Level 3

CONDITIONALLY AUTOMATED
- Congestion Assistant
- Highway Driving
- Auto Parking

Level 4

HIGHLY AUTOMATED
- Driver partly out of the loop
- City Pilot

Level 5

FULLY AUTOMATED
- No control interfaces for a human driver
- Robot taxi

- Higher levels of automation need higher levels of connectivity

Challenge today
Proof of effectiveness and reliability

- 99,999% of all critical situations: Human drivers succeed
  →*The self driving algorithm also?*
- "Autopilot" keeps/changes lanes and brakes automatically
- Wireless transfer of software updates

Regulatory „grey" area, Customer = Test driver

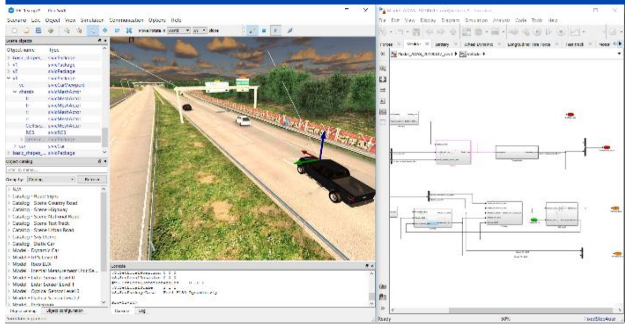
Challenge tomorrow
IT Security and Functional Safety

- Relevant safety gaps in software directly linked to hardware
- Hackers could gain control over essential vehicle functions
- AI in ASIL rated vehicle functions

Homologation by physical and virtual testing ?

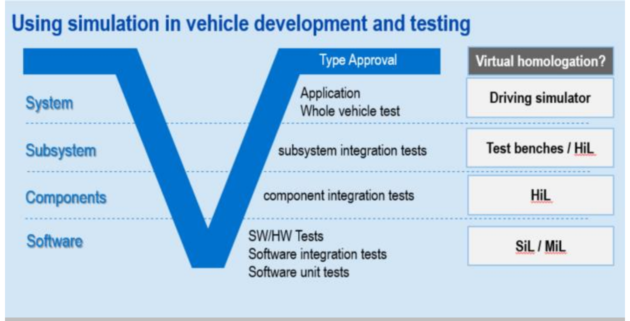
Approach for validation and approval of ADAS and AV

Simulation / Virtual tests



- ☑ Analysis of a huge number of scenarios, environments, system configurations and driver characteristics
- ☑ Abstraction: scenario (KPIs), environment, HW (vehicle)

Semi-virtual tests / XiL test bench



- ☑ Test benches / XiL
- ☑ Driving simulator
- ☑ Abstraction: scenario (KPIs), environment

Proving ground tests

- ☑ Reproducibility by use of driving robots, self driving cars and targets; critical maneuvers are possible
- ☑ Abstraction: scenario (KPIs),

Field tests

- ☑ Approval in real driving situations and comparison with system specifications
- ☑ Real world

10^8 scenarios → 10^3 scenarios → 10^2 scenarios

Subset for approval

Model Database

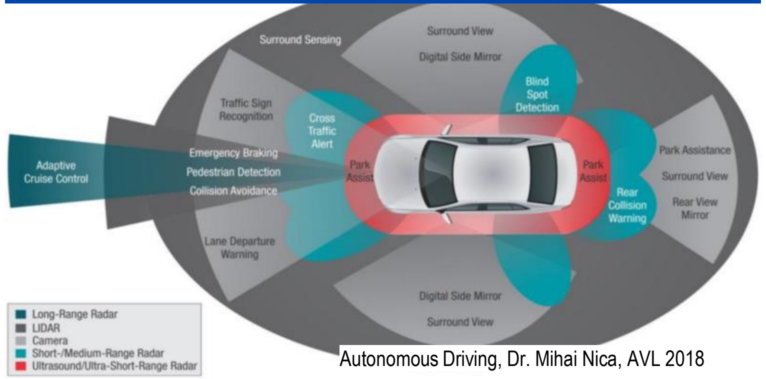
- Scenarios (exposition, environment, …)
- Road Users (driver, pedestrian, …)
- Vehicle (driving dynamics, …)
- Sensors (radar, lidar, camera, …)

Uncertainties & simplifications

Effort for coverage of all relevant scenarios & environments

Virtual model validation and verification

Sensor model

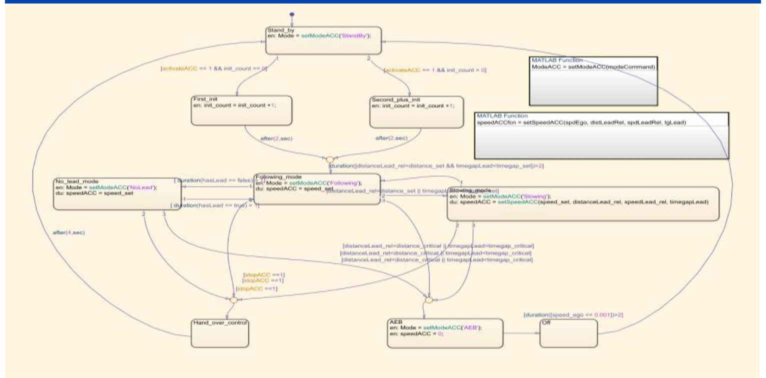


Autonomous Driving, Dr. Mihai Nica, AVL 2018

- **Source: Internal knowledge, internal scenario database**

- Field of view test
- Unambiguous identification test
- Harsh weather conditions
- Corner case scenarios

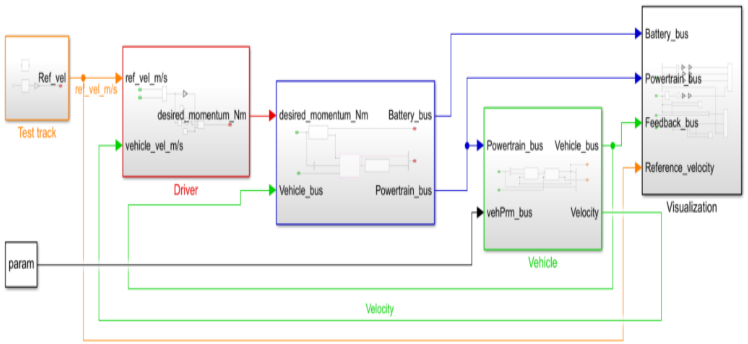
ADAS function



- **Source: ENCAP, ISO standards, int. knowledge and scenario database**
  - Focus: ACC and AEB

- Following test & operational limits (ACC)
- Following test aggressive (ACC + AEB)
- Following with speed oscillation (ACC)
- Cut-in & Cut-out (ACC)
- Performance on curve
- (NCAP) Emergency braking CCRs
- (NCAP) Emergency braking CCRb
- (NCAP) Emergency braking junction
- ……..

Vehicle dynamics model



- **Source: ISO Standards, internal knowledge**
- Braking test
- Acceleration test
- ISO 4138:2004 – Steady state circular driving
- ISO 3888-2:2002 – Severe lane change
- ISO 7401:2011 – Lateral transient response test
  - Steering wheel step input
  - Steering wheel sinus input – one period
  - Steering wheel sinus input - continues
- ………

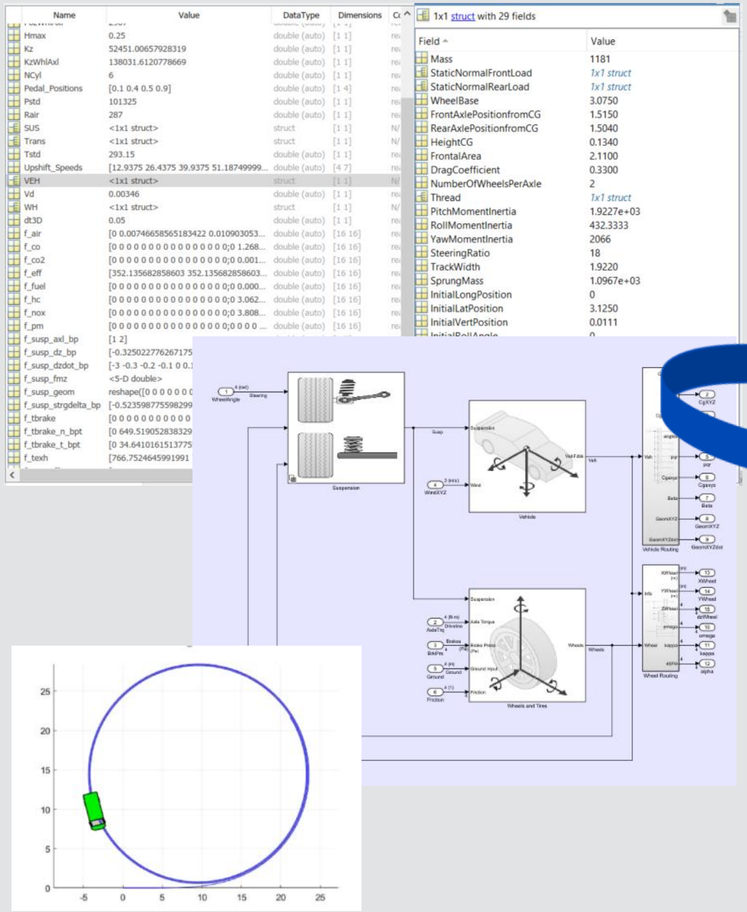
Vehicle dynamics virtual model validation and verification

Determination and identification of parameters

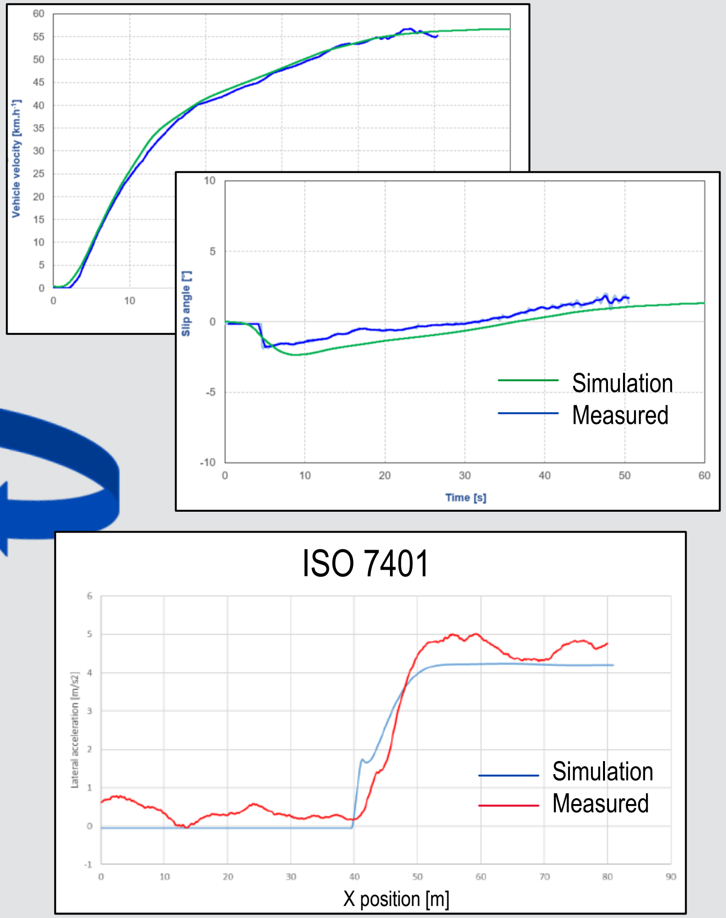
- Static physical tests

- Dynamic physical tests

Parametrization of simulation models



Correlation of results and approval of simulation



Components for scenario-based testing, TÜV SÜD Czech test environment

- Test track near Prague
- Airfield Mnichovo Hradiště
- NCAP junction
- Highway lanes

- OXTS RT-Base S
- Track-Fi Power Mesh (radio)
- ABD control station and nets
- Full ABD Synchro software

- ABD SR15 Orbit driving robot
- ABD CBAR600 pedal robot
- OXTS RT-3003 IMU
- Track-Fi Power Mesh (radio)

- ABD moving platform, ver.2018
- OXTS RT-3003 IMU
- ABD Soft target, rev. F
- The only approved target for EuroNCAP

Using Simulation for approval of ADAS and AV

Motivation for simulation (virtual methods)

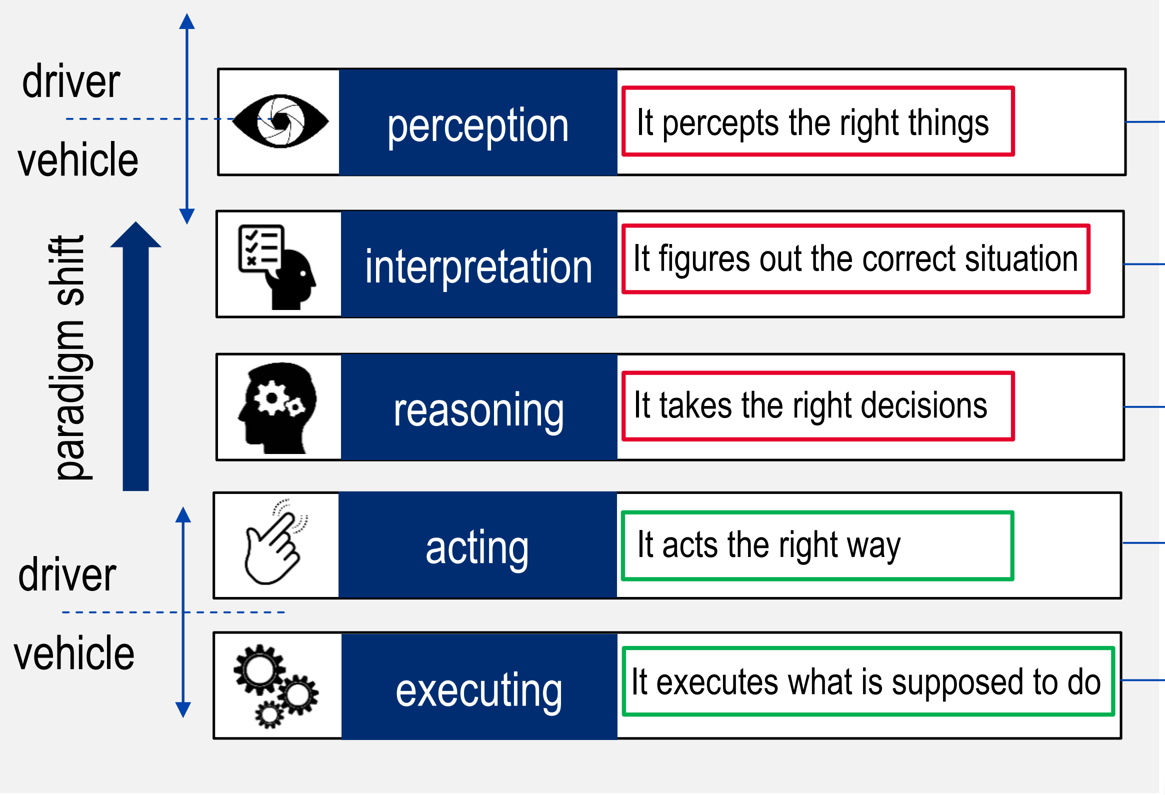
- Vehicle variant complexity
- Increasing active systems
- System complexity

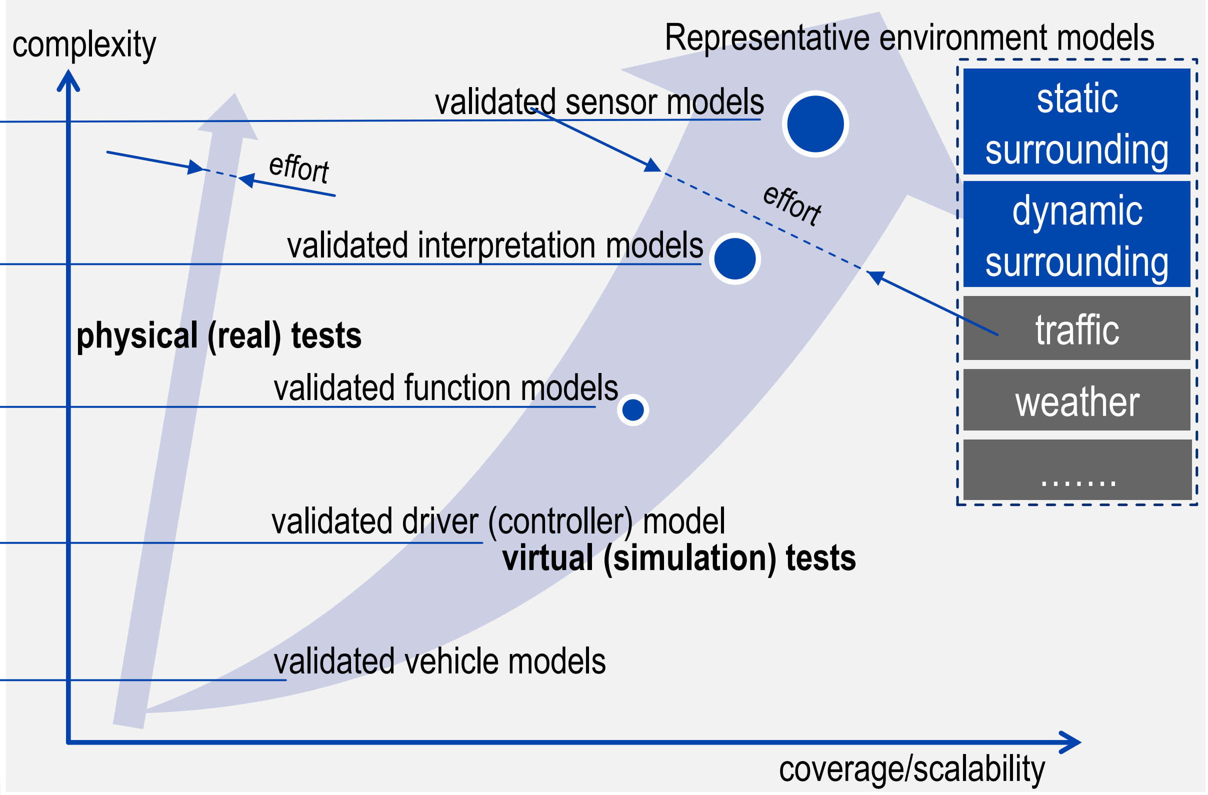
⇨

- Huge testing parameter space
- Not reasonably coverable by physical testing
- Limitation of physical testing

⇨

Highly relevant for ADAS and for automated driving

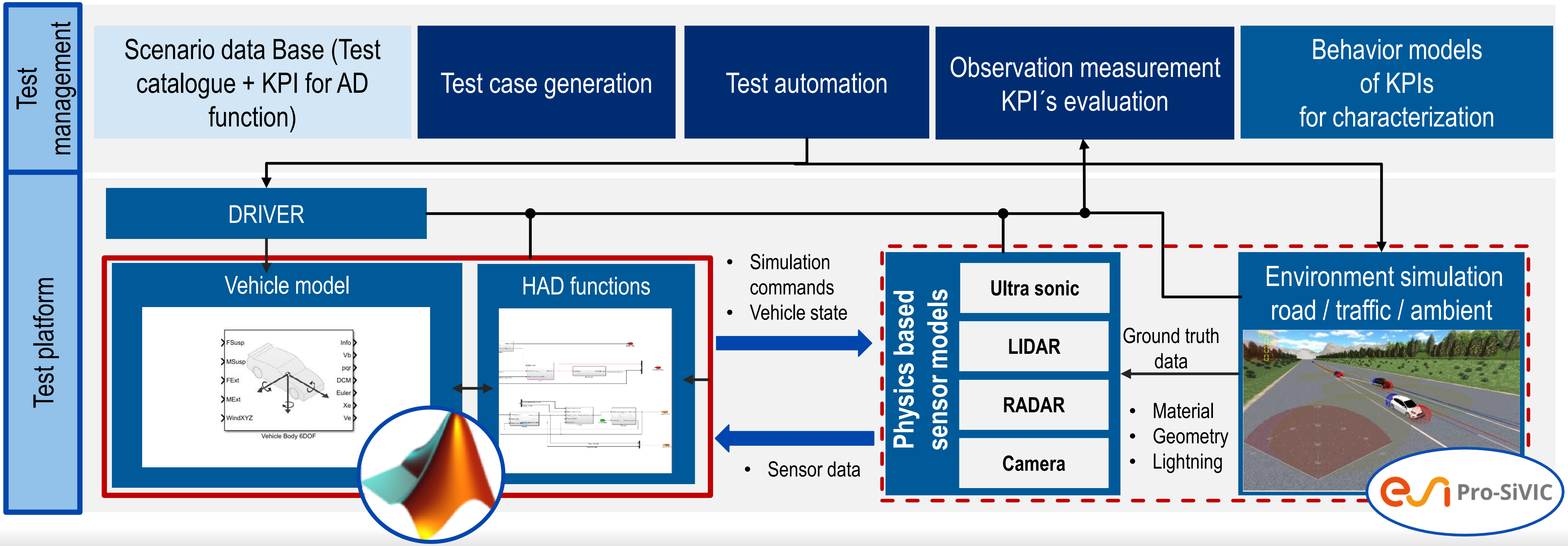




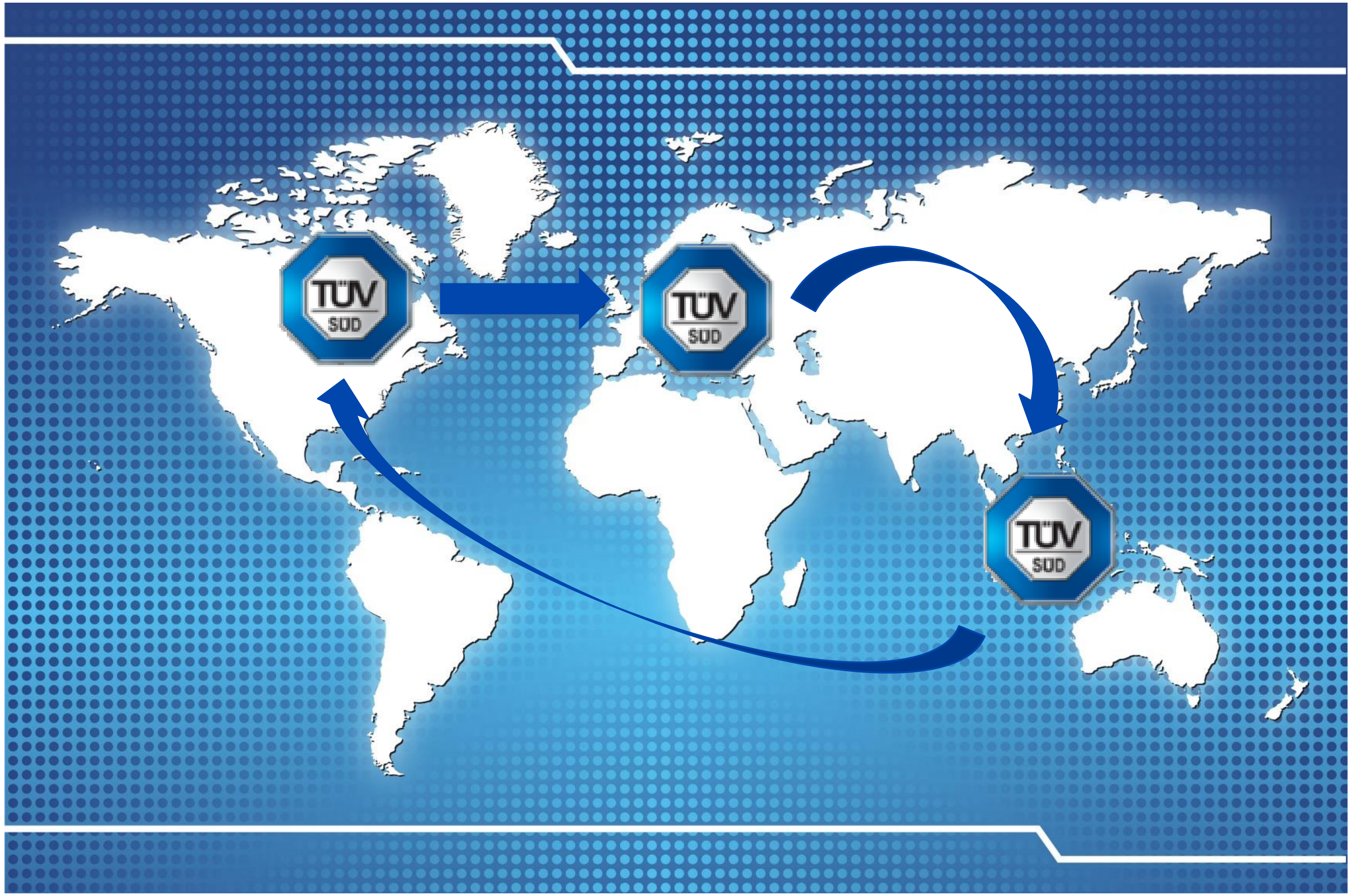
Test Platform Architecture for Virtual validation and approval of AV

The most efficient validation and homologation will be done by those who will use the best combination of different test environments.
Dr. Tobias Düsler, Department Manager Advanced Solution Lab., AVL, March 2019

Co-simulation between Matlab/Simulink and Pro-SiVIC. Utilizing automation and time domain simulation of Matlab/Simulink with high fidelity sensor models and virtual environment representation of Pro-SiVIC



Managing cooperation in global team



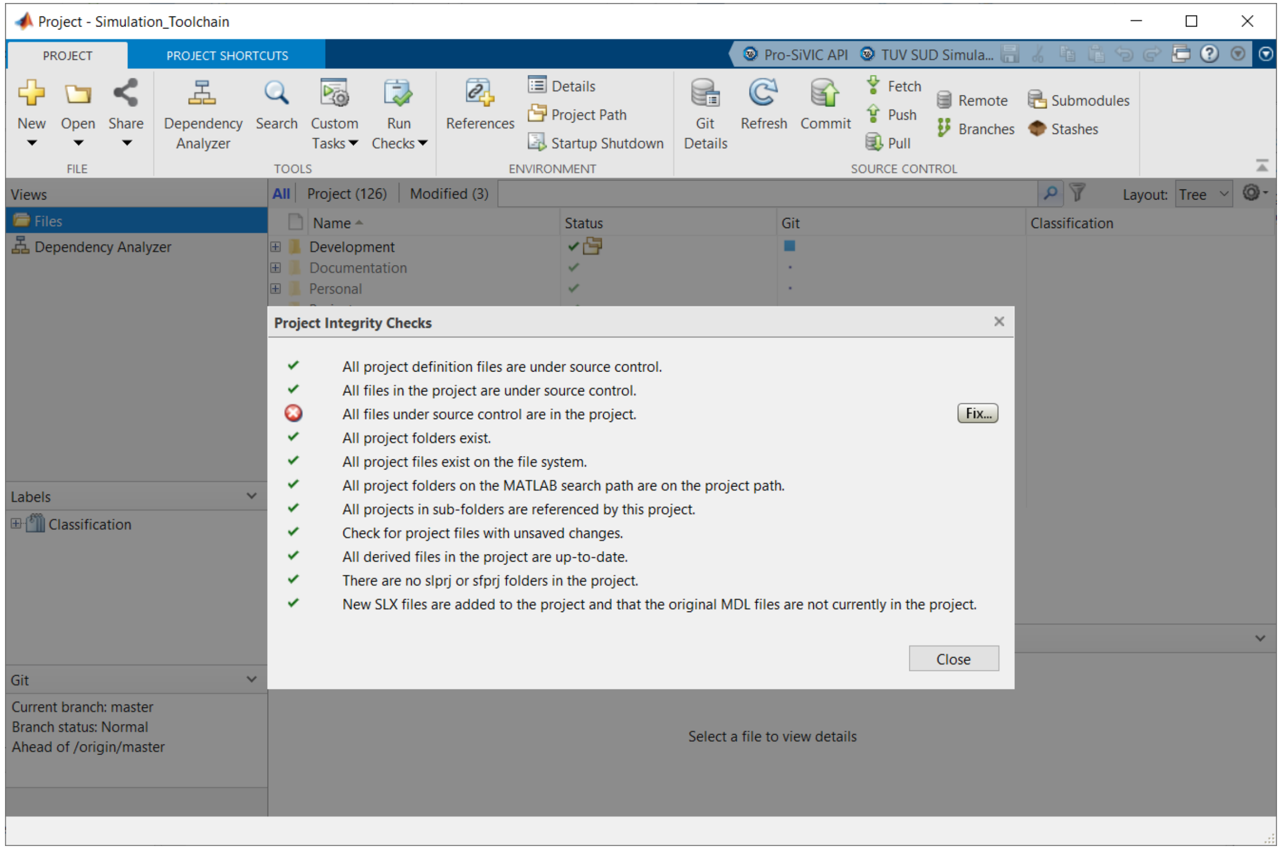
Managing cooperation in global team - solution

Requirements:

- Easy way of data sharing
- Unified simulation environment
- Repeatable simulation execution
- Change management
- File back-up system

Solution:

- Using Matlab Projects with integrated Git



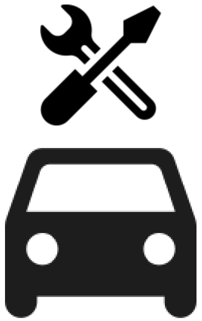
Using Apps to speed up workflow - motivation

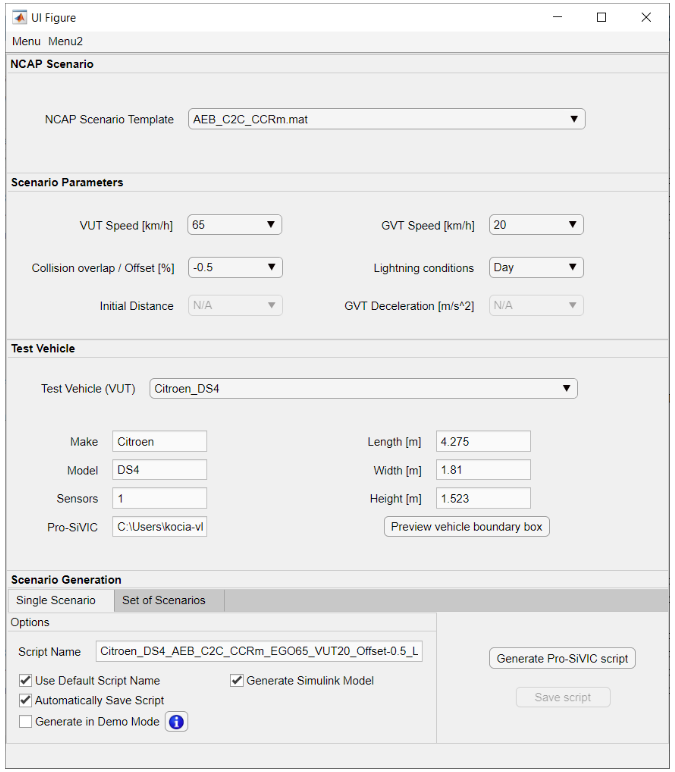
Sharing work through code, when there is a big space for parameter variation and wide range of different user settings is ineffective.

- Every user needs to be familiar with code
- User needs to know what to change and where
- Potential to break the code

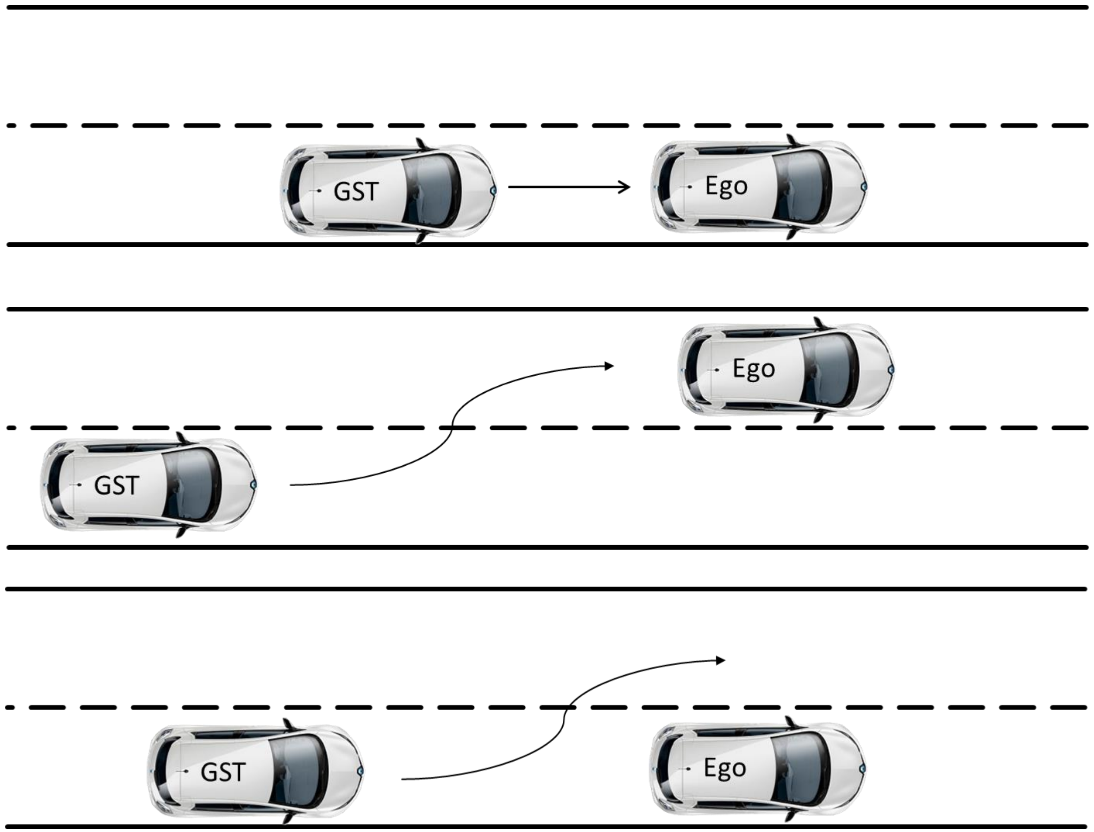
```
%% This is a very complex program

path = 'C:\Program files\ ...';
param1 = 0.7; % DONT TOUCH THIS!!!

tempVariable_spd = 90/3.6; % EDIT this value
speedTSV = 70/3.6; % EDIT this only if you
% are sure what you are doing!

KPIsToUSE = {'TTC','MaxSpeed','MeanSpeed'};
% For full list of KPIs see file: KPIsFULL.txt

%% Initial conditions & initialization
%
% code
% code
% code
```

Using Apps to speed up workflow - example





Illustrative application front-end



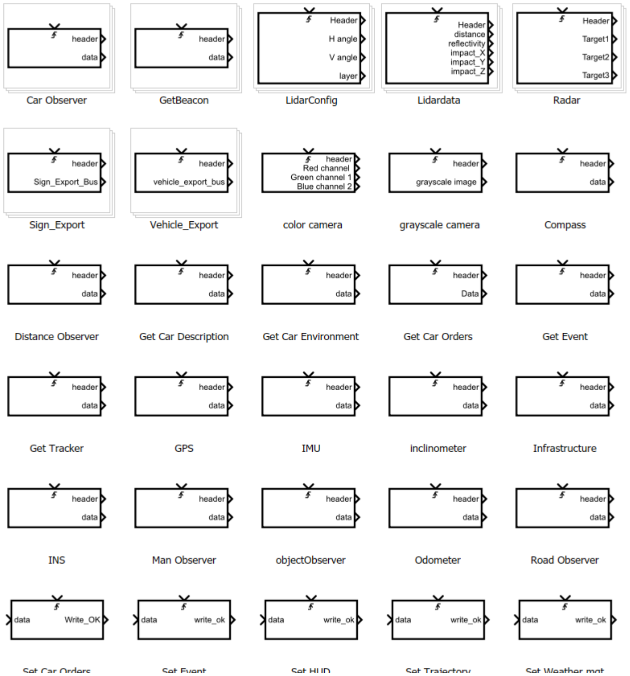
Pro-SiVIC as a source of synthetic sensor data

- Virtual representation of environment
- High-fidelity sensor models
  - Radar
  - Lidar
  - Camera
  - Other commonly used sensors
- Lightning conditions
- Weather management system

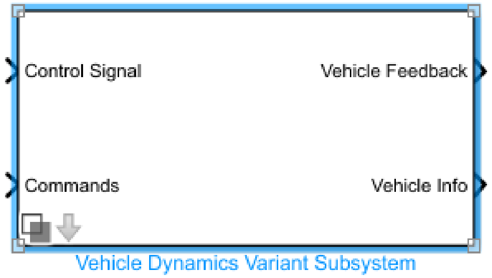
Virtual Testing

Using simulation data in Simulink

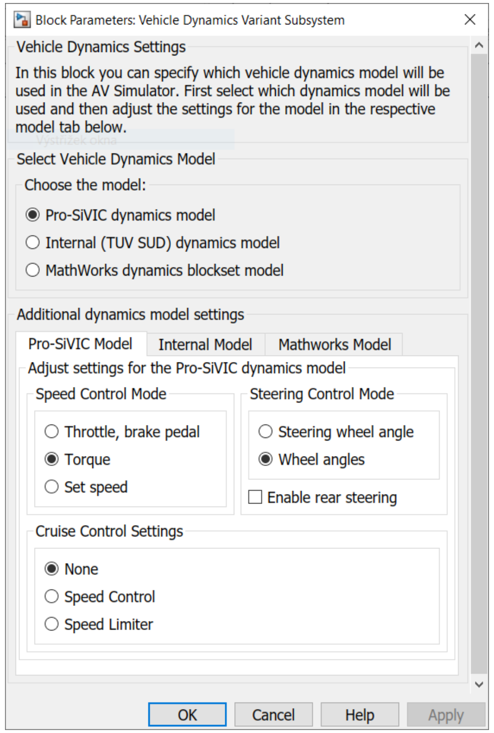
- Basic data transfer functionality provided by precompiled mex functions
- Specific functionality reached by combining basic blocks intro masked specific-purpose subsystems



Pro-SiVIC data transfer



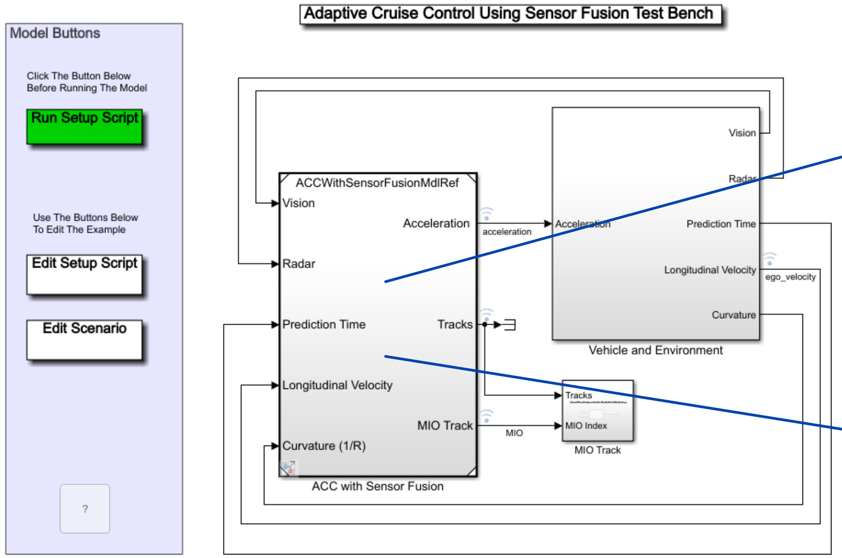
Specific-purpose block

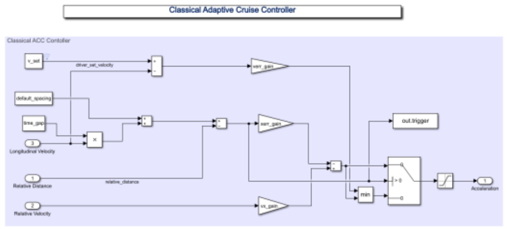


Typical block mask for user interaction

Head start using prebuilt examples

- TÜV SÜD is not a software developer, but we need a proof of concept for our platform
- Taking and adapting prebuilt algorithm examples allows to quickly assess the functionality of whole platform without having to spend time coding the algorithms

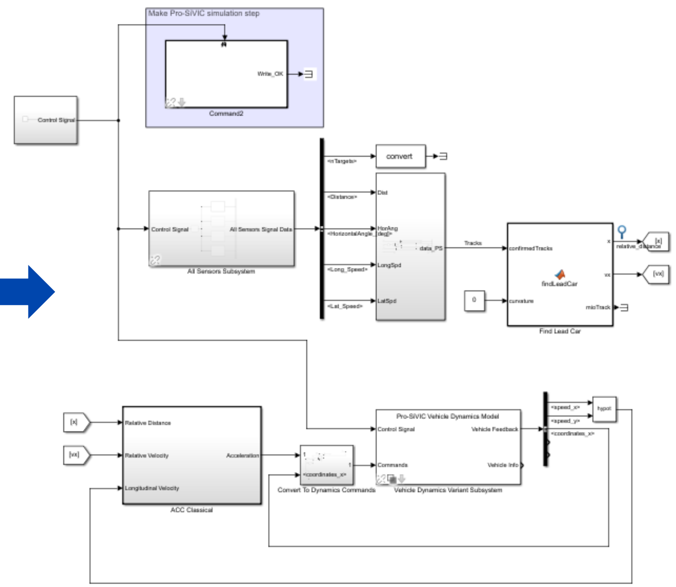




ACC controller

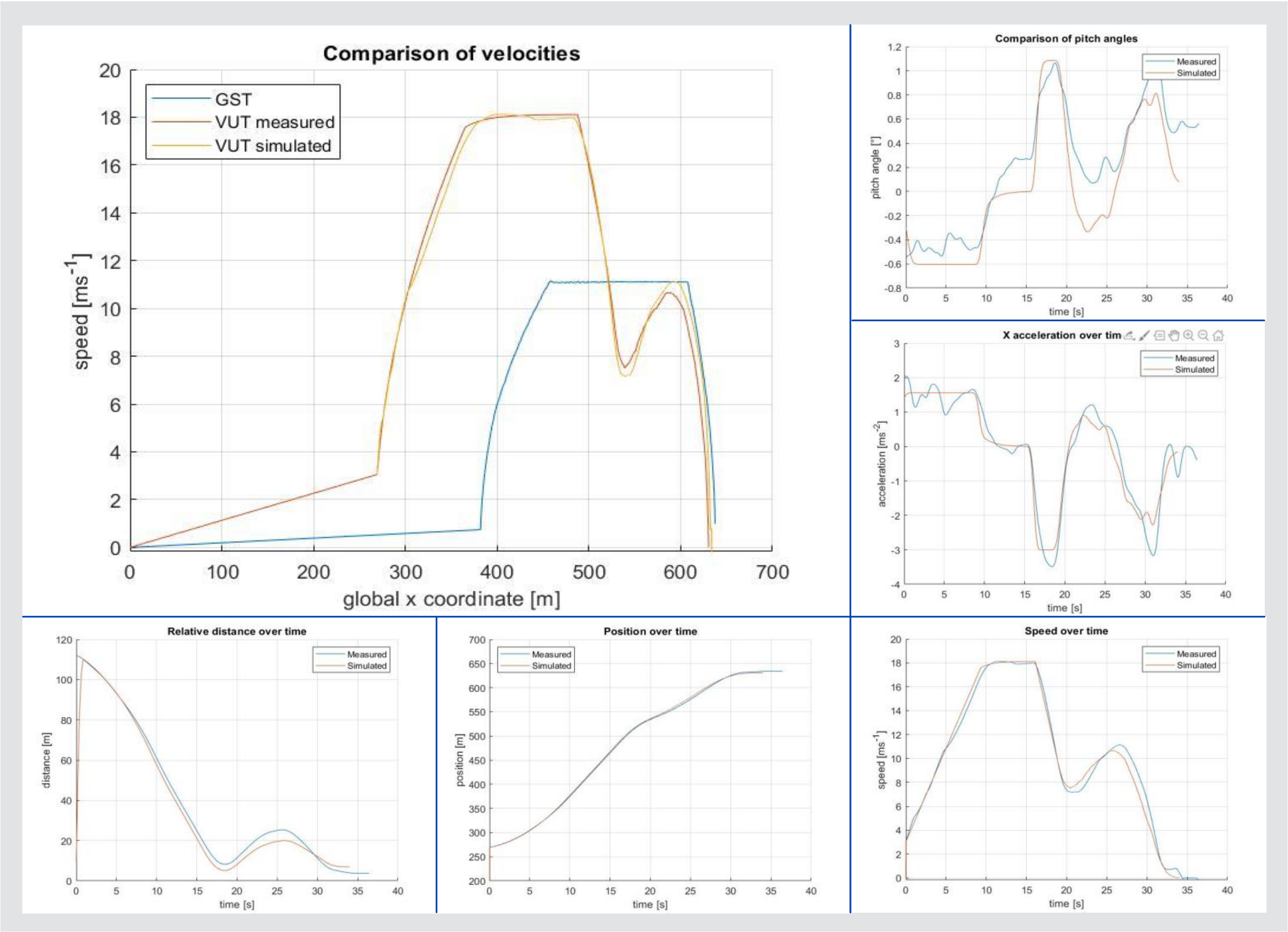
```
maxX = 1000;  % Far enough forward so that no track is expected to exceed this distance
trackID = 0;

for i = 1:1
    x = confirmedTracks(1); % Longitudinal position of the track relative to ego
    y = confirmedTracks(2); % Lateral position of the track relative to ego

    if x < maxX && x > 0 % No point checking otherwise
        yleftLane  = polyval([curvature/2, 0,  halfLaneWidth],x); % Half a lane to the left
        yrightLane = polyval([curvature/2, 0, -halfLaneWidth],x); % Half a lane to the right

        % Find a new lead car
        if (yrightLane <= y) && (y <= yleftLane)
            maxX = x;
            trackID = i;
        end
    end
end

if trackID>0
    mioState = confirmedTracks;
else
    mioState = [inf inf inf inf inf];
end

% Output:
x = mioState(1);    % Longitudinal position of the lead car
```

Lead vehicle detection



ACC behavior simulation

Simulation results



UN Regulation No. 140 – ESC

Annex 4 – Dynamic stability simulation tool and its validation

„2.3. The simulator shall be deemed to be validated when its output is comparable to the practical test results produced by a given vehicle type during the dynamic maneuvers of paragraph 9.9. of this Regulation. The relationship of activation and sequence of the vehicle stability function in the simulation and in the practical vehicle test shall be the means of making the comparison.“

Thank you for tuning in!

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