PRYSTINE will realize Fail-operational Urban Surround perception (FUSION) which is based on robust Radar and LiDAR sensor fusion and control functions to enable safe automated driving in urban and rural environments.

PRYSTINE Key Safety Challenges & Results

The Autonomous Workshop: Safety, Research & Innovation

Prof. Dr. Eng. George Dimitrakopoulos, Infineon Technologies AG & Harokopio University of Athens

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29.09.2021, Vienna

ECSEL Joint Undertaking

Electronic Components and Systems for European Leadership

AGENDA

PRYSTINE Key Safety Challenges & Results

1. Introduction

- Overview
- Vision and expected outcome

2. Safety challenges and technology enablers in autonomous mobility (selected project results)

- Components LiDAR, Radar and safety controllers for FUSION
- Fail-operational and high-performance Automated Driving Systems
- Optimized E/E architecture for FUSION-based automated vehicles
- Functionally-safe perception and fusion algorithms

3. Conclusions

PRYSTINE – Programmable Systems for Intelligence in Automobiles

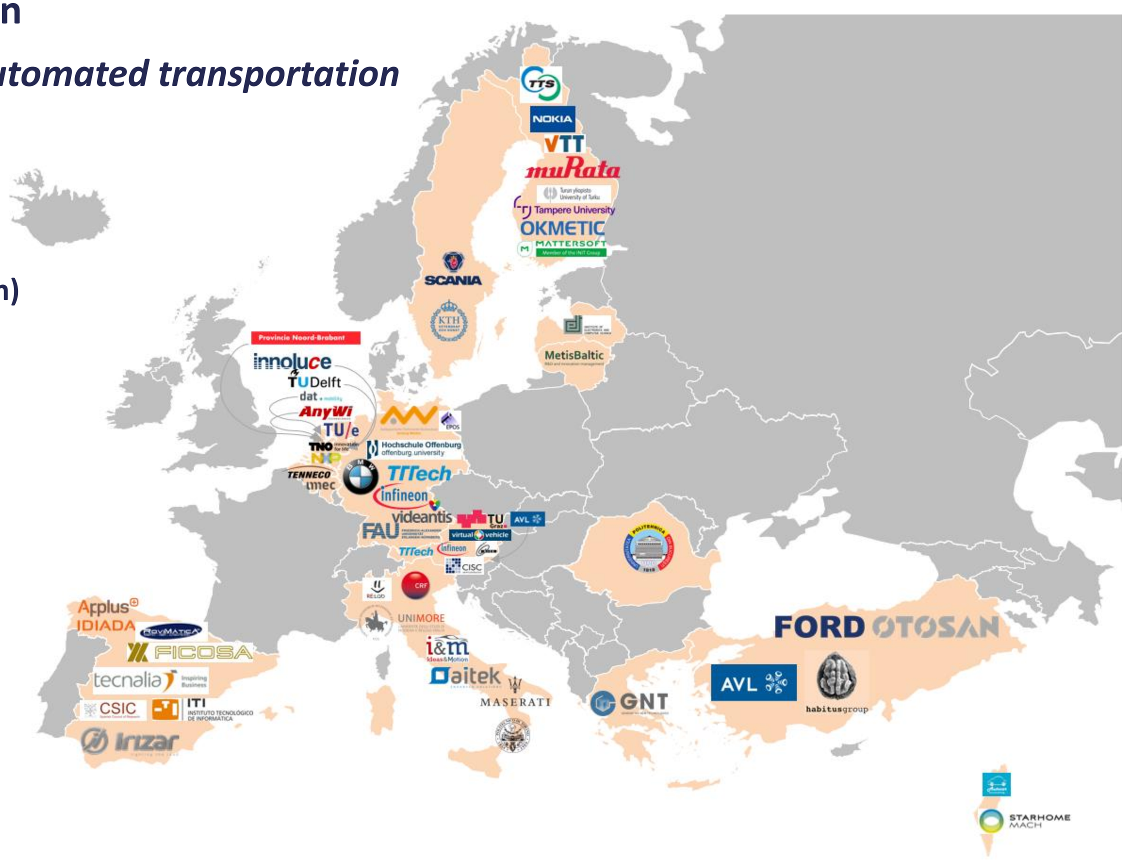
- EU H2020 framework, ECSEL-2017-2 call, **Research and Innovation Action**
- Application: **Smart Mobility, *ECS for partial, conditional, highly and fully automated transportation***
  - Automation of vehicles aiming at fully autonomous driving
  - Enabler: highly automated driving functions (ADFs) to master the Grand Societal Challenges “Individual Mobility” and “Energy Efficiency”
  - Major challenge (also PRYSTINE’s focus area)
    - **The step from SAE Level-2 (Partial automation) to SAE Levels-3 (Conditional automation) and above**

- Consortium of **60 project partners** across **14 European and non-European countries:**
  Leading automotive OEMs
  Semiconductor companies
  Technology providers
  Universities and research institutes

- **Coordinated by Infineon Technologies AG** (DE)

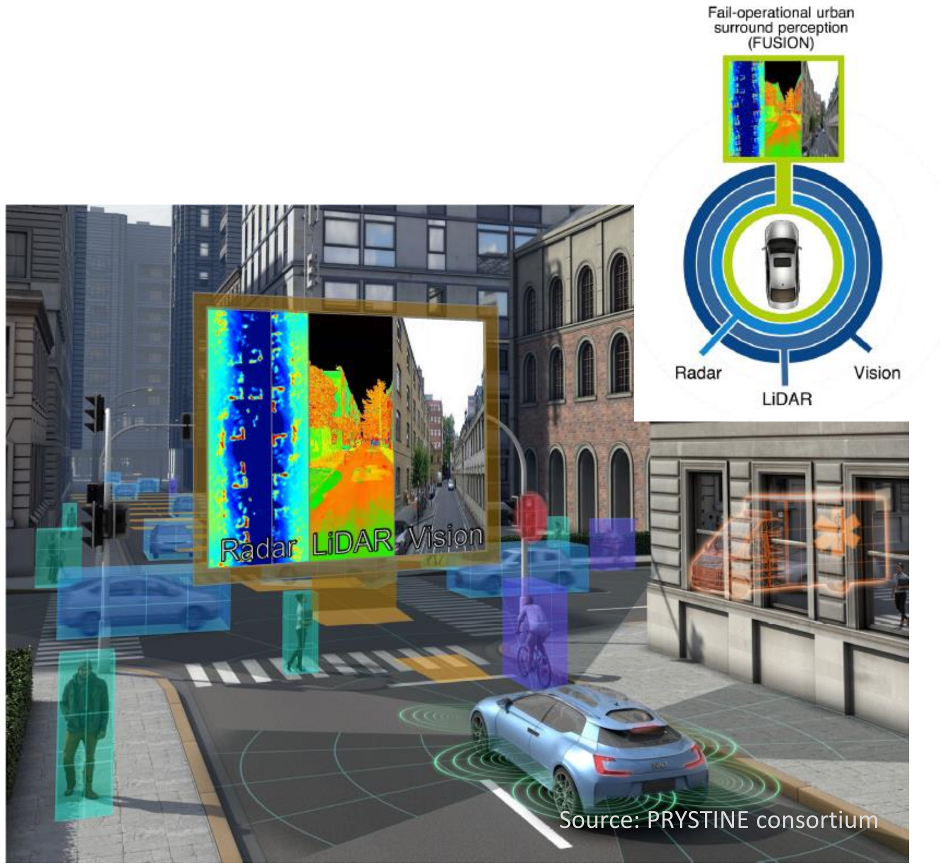
- **Funding**: approx. 29Meuros (EU and national grants)

- **Duration**: 01.05.2018 – 31.10.2021



Visit our project website: https://prystine.eu/

PRYSTINE vision and expected outcomes



Overall project vision

Realize Fail-operational Urban Surround perceptION (FUSION), based on robust Radar and LiDAR sensor fusion and control functions, so as to enable safe automated driving in urban and rural environments.

<u>Therefore achieve:</u>

1. Enhanced reliability and performance, reduced cost and power of FUSION components
2. Dependable embedded control by co-integration of signal processing and AI approaches for FUSION
3. Optimized E/E architecture enabling FUSION-based automated vehicles
4. Fail-operational systems for urban and rural environments based on FUSION

Expected outcomes:

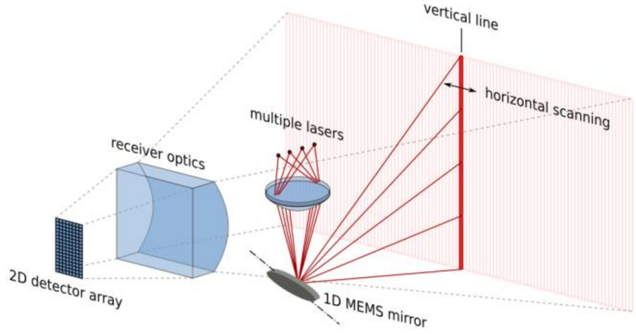
- Fail-operational sensor-fusion framework at component level
- Dependable embedded E/E architectures
- Safety compliant integration of Artificial Intelligence (AI) approaches for object recognition, scene understanding, and decision making within automotive applications
- The resulting reference FUSION hardware/software architectures and reliable components for autonomous systems will be validated in numerous industrial demonstrators

Components LiDAR, Radar and safety controllers for FUSION

***Enhanced reliability and performance, cost and power** of Fail-operational Urban Surround perception (FUSION) components*

Vision:

- Implementing and achieving FUSION – Fail-operational Urban Surround perception via **novel semiconductor components**
- Research and development of dependable sensor systems
  - CMOS-based **Radar**
  - **1D** and **2D** MEMS-based **LiDAR**
- Development of next-generation safety controllers
  - **AURIX 3rd Generation**



Infineon's 1D LiDAR working principle

Infineon's AURIX™ Safety Controller

Infineon's
1D MEMS Mirror

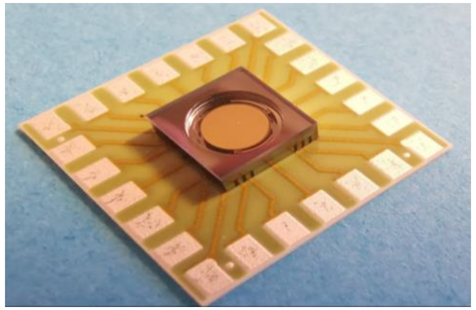
Infineon's 1D MEMS-based
LiDAR Demonstrator

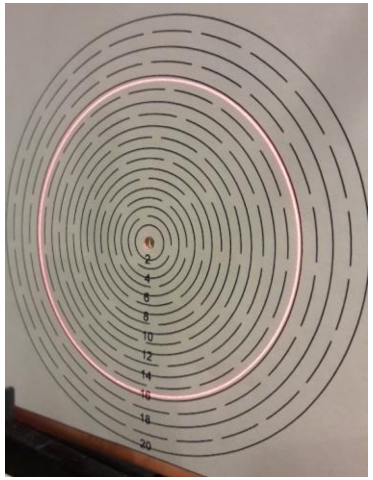
Key safety challenge:
Components for dependable and robust environmental perception

Components LiDAR, Radar and safety controllers for FUSION: advances and demonstrators

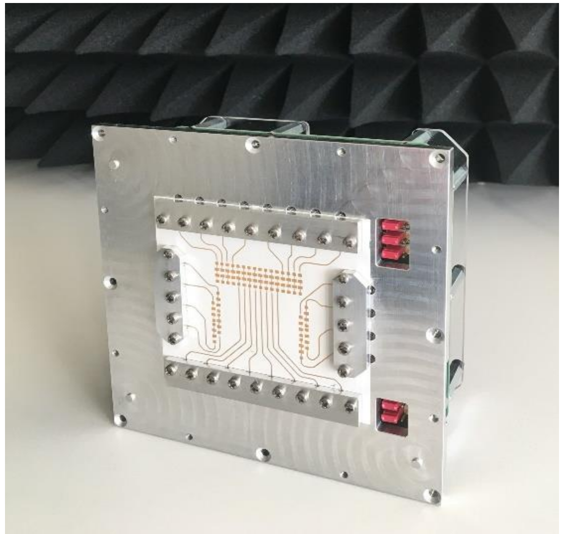
Key advancements compared to state-of-the-art:

- **Fail-operational** sensor compounds vs. fail silent individual sensing approaches
- **Reduced false-positive detections** at component level via advanced signal processing
- **Power** and **cost** reductions and **margin** improvements of semiconductor components

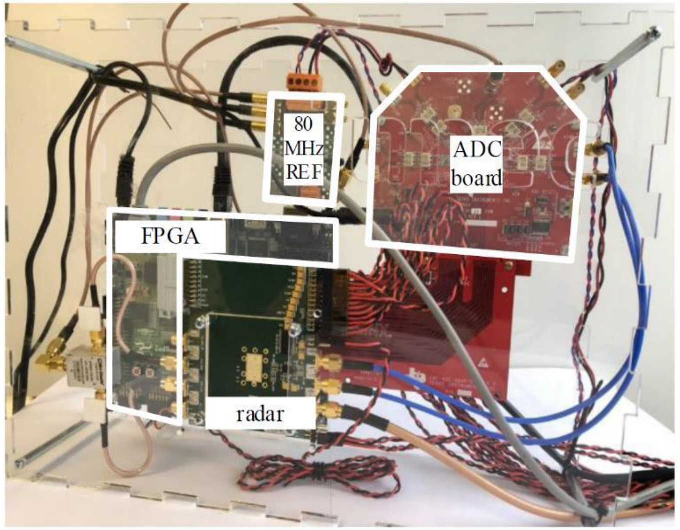




Murata's 2D MEMS Mirror and 2D LiDAR demonstrator



Infineon's High-Resolution Radar demonstrator with **8 transmitters (TX) and 16 receivers (RX)**



IMEC's scalable 60-GHz Radar designed in 28nm CMOS technology

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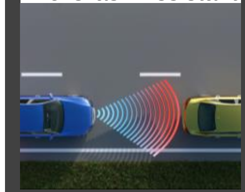
TTTechAuto

Fail-operational and high-performance Automated Driving Systems

*Deployment of the **best-in-class COTS components** to enhance the existing architectures and to **design safe ADSs** to enable highly automated driving*

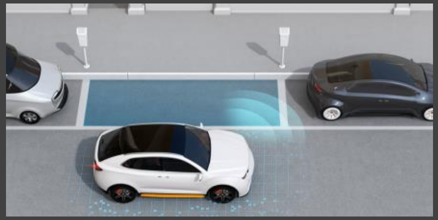
Active Safety

Pre-Crash Assistant



AEB

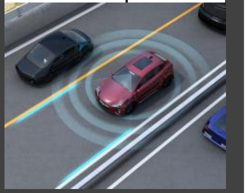
Parking Assistance



Driving Assistance

Cruise Control

Lane Keep Assist



L0
Driver only

L1
Driver assistance

L2
Partial automation

L3
Conditional automation

L4
High automation

L5
Full automation

Urban Pilot / MaaS

Traffic Jam Pilot

Valet Parking

Highway Pilot

Autonomous trucking

<u>Key safety challenge:</u>
Functional safety and fail-operational performance of new systems

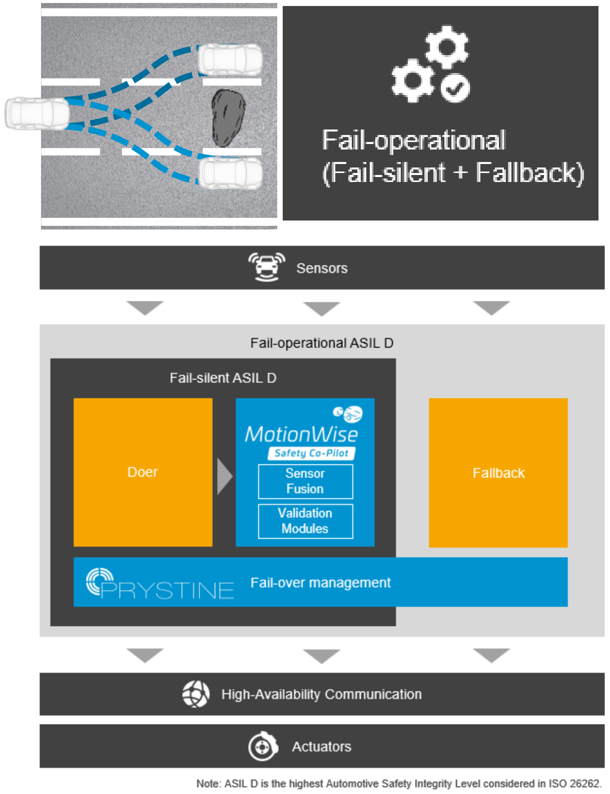
Levels of autonomy according to scheme proposed by the Society of Automotive Engineers (SAE).

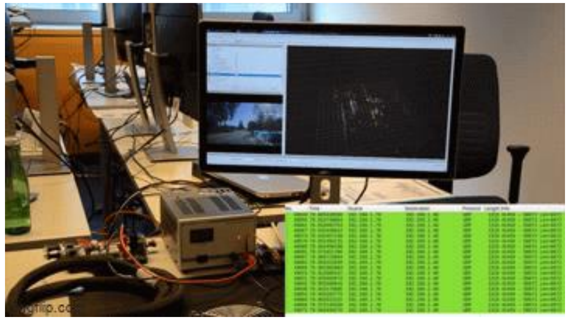
Fail-Operational Autonomous Driving Platform (FOADP)

- ✓ *Mixed-criticality modular architecture instead of federated architecture deploying SoCs, AURIX© microcontroller, Deterministic Ethernet switch & a fail-over mechanism to ensure non-compromised sensor fusion for automated driving (a SAE Level 3+ equivalent solution for Automated Driving Systems)*
- ✓ *Enhance safety HW architecture concepts up to ASIL D using Infineon's Aurix microcontroller (AURIX™ TC3x devices are certified ASIL D by TÜV Saar based on ISO26262-18) vs. other approaches (e.g. with/without* Voluntary Safety Self-Assessment | NHTSA *)*
- ✓ *Higher performance vs. NVIDIA's DRIVE PX2 platform (1 TOPS on* Tegra X2 */ 30 TOPS on* Xavier*)*
- ✓ *PC transmits pre-recorded sensor data to FOADP as well as receives results from FOADP, serves as front-end for the fused sensor data, sensor fusion application deployed*
- ✓ *Fail-over time improvement of approx. factor 2.5 comparing to previous projects*
- ✓ *Ongoing analysis of compatibility with ISO/AWI TS 5083 Road vehicles — Safety for automated driving systems — Design, verification and validation (successor of ISO/CD TR 4804 Technical Report)*

- ✓ More details here: https://www.linkedin.com/feed/update/urn:li:activity:6763024916150321152/

  Evaluation of a Fail-Over Mechanism for 1oo2D Architectures in Highly-Automated Driving | IEEE Conference Publication | IEEE Xplore





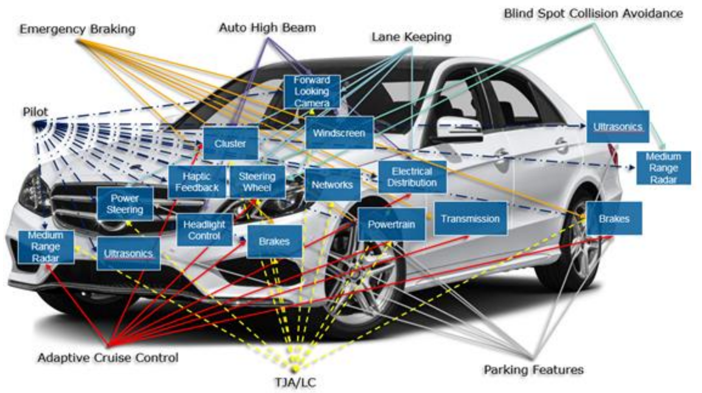
Optimized E/E architecture for FUSION-based automated vehicles

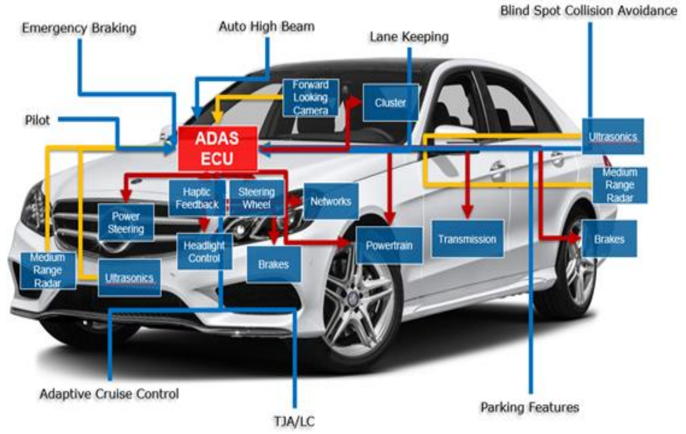
*Building on the scene understanding from components and systems provides **E/E architecture, associated components and FW to improve safety** by enabling the system to respond to the scenes when facing erroneous operation*

Vision: *Incorporating* PRYSTINE's ***fail-operational*** and optimised sensors, components, embedded safety controllers, processing systems with ***dependable*** vehicular electrical/electronic infrastructure and communication systems – thus ***enabling FUSION***

To guarantee required **safety level and dependability** in general for driving automation, Prystine is delivering:

- Solution for **distributing intelligence** at E/E level involving easy integration and simplified implementation
- **Realistic modelling** to ease development
- Improved **QoS for V2N** communication of safety critical systems

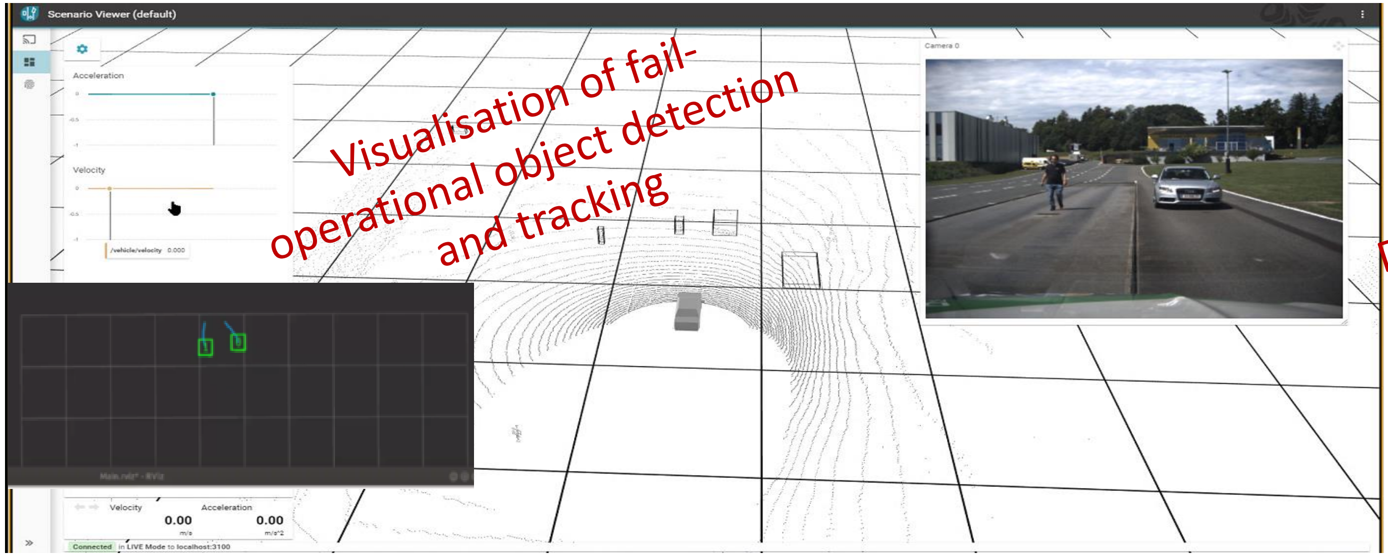


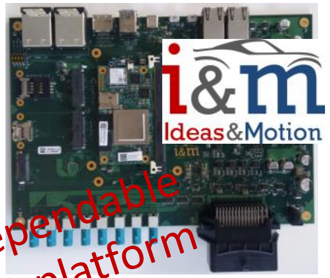


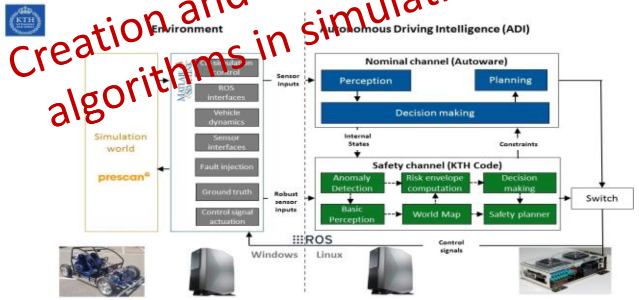
Key safety challenge:
Guaranteeing safe E/E operation even in the event of error

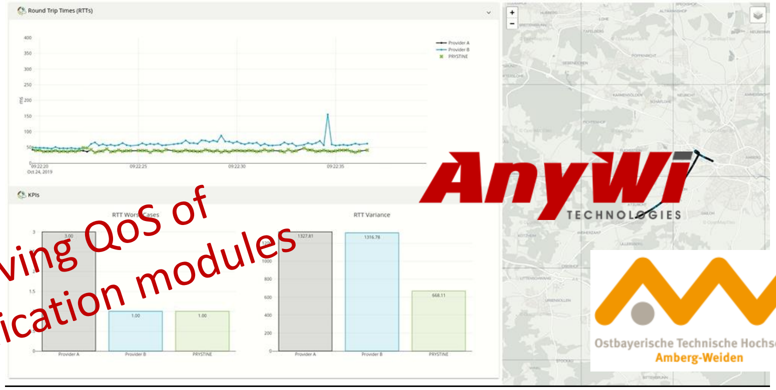
Dependable architecture implementations

- *Fail-operational aspect underlines the need to detect and deal with the erroneous operation*
- *Achieving desired fail-operational level is based on detection of artificially injected errors to test effectiveness of new algorithms and HW setups (e.g. parallelisation)*









AVL virtual vehicle CISC

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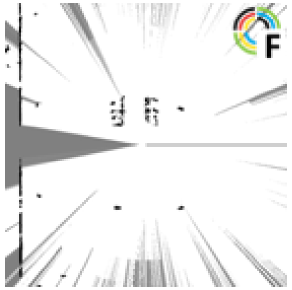
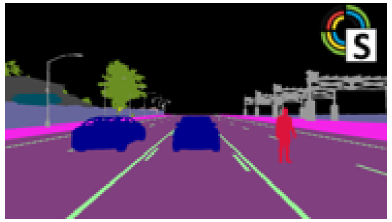
Functionally safe perception and fusion algorithms

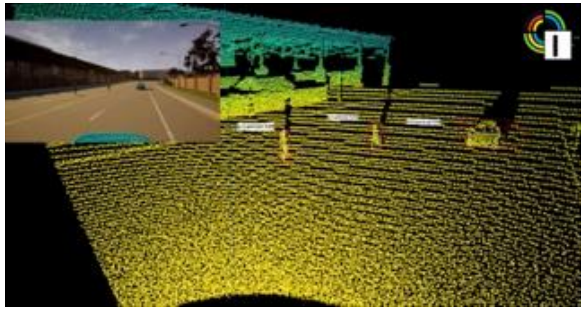
virtual vehicle

***Scene understanding** as a key enabler for robust safe and reliable environment perception in complex ODDs e.g. harsh weather conditions, complex urban and rural scenarios*

- Scene understanding is referred to **detect, classify and predict the intended motion** of all identified objects in the current operating scene
- To realize this vision several **key FUSION building blocks** were developed, fused, deployed and verified in different use case scenarios







Occupancy grid **F** iltering

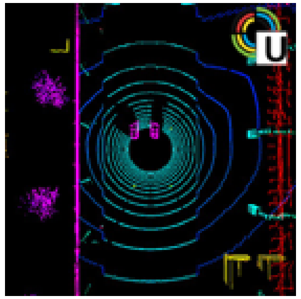
Point clo **U** d segmentation

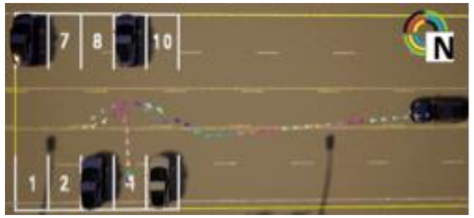
S emantic segmentation

Object detect **I** on

Multi- **O** bject tracking

Path pla **N** ning for parking





<u>Key safety challenge:</u>
Everything you are not able to understand you cannot react on

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AI-supported FUSION involving Radar, LIDAR, Camera

- *DriveByWire system, object recognition utilizing DNN and decision making integrated in the* ***KIA SOUL EV passenger vehicle***

✓ *A novel approach to software component integration using within the PRYSTINE project developed COMPAGE framework (fail-operational system component management framework) and AI-based algorithms capable of identifying faulty sensors by analyzing data of different types, e.g. LIDAR, Radar, cameras*

✓ *Aurix-based Emergency Braking system and Linux based debug GUI SW for automotive applications – a proof-of-concept systems*

✓ *Successful execution of 100% of the scenarios with an injected artificial failure (sensor connection interruption, distortion of camera images)*

✓ *A novel ability to detect sensor failure and faulty components by utilizing supervisor ANN and distributed architecture Failure detection success rate, ratio between injected failure and detected by the system*

✓ *See:* https://www.edi.lv/en/edi-researchers-are-participating-in-european-forum-for-electronic-components-and-systems-efecs/

✓ *Automatic Emergency Braking scenario*: https://www.youtube.com/watch?v=6_0ch9_m13U

- *Passenger vehicle for low-speed autonomy application on the* ***FORD passenger and heavy-duty vehicles***

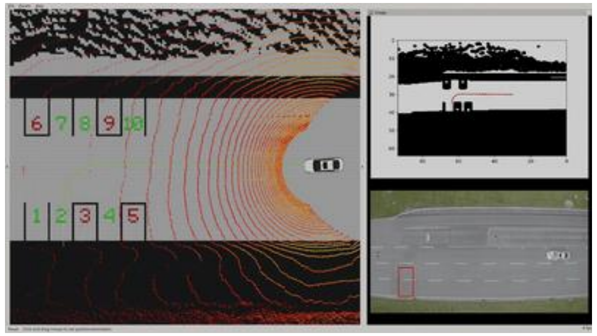
✓ *Fusion algorithms and perception components to be utilized by SAE Level 3+ equivalent autonomous parking and low speed autonomy solutions*

✓ *Related to Automated Parking Vale Systems like by a few OEMs/Suppliers (Bosch, Mercedes, Tesla, Ford, etc.), particularly in the passenger car segment*

✓ *The proposed solution fits park-valet systems both for passenger and commercial vehicle segments*

✓ *Advance SotA due to the provision of fail-operationality and robustness by the utilization and fusion of multiple sensor sources including cameras, LIDAR and Radar*

✓ *Watch the results here:*
Path planning for parking https://www.youtube.com/watch?v=OV1AdaRoUd0
Multi-Object Tracking: https://www.youtube.com/watch?v=xVZKEfezkZI
3D Object detection: https://www.youtube.com/watch?v=Pr71kOZ-OW0
Occupancy grid filtering: https://www.youtube.com/watch?v=YR8K2sN453Q
Semantic segmentation: https://www.youtube.com/watch?v=QANzA4D8duc



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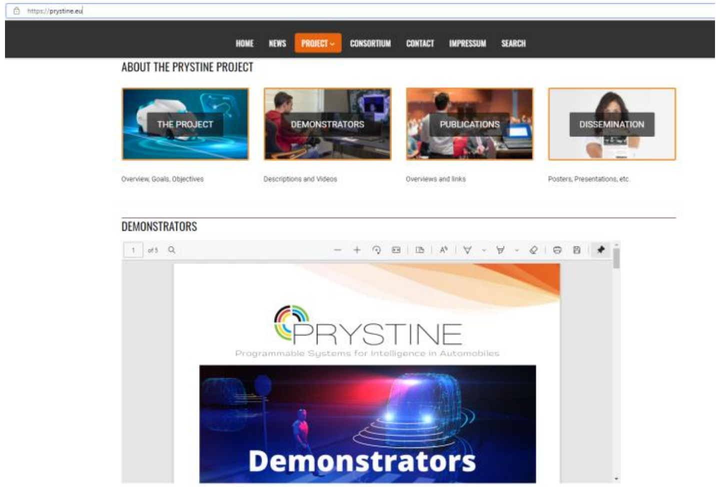
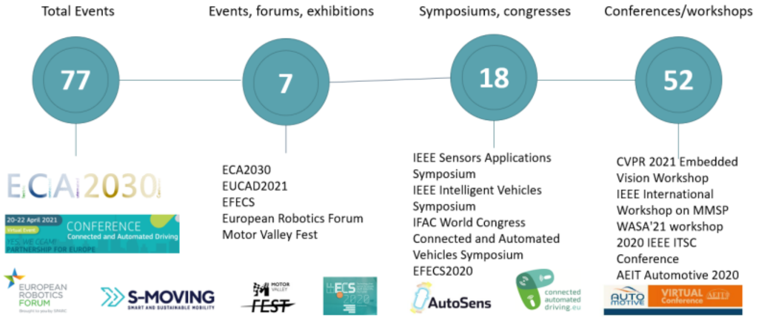
Conclusions

- Fruitful **collaboration** of SMEs together with large enterprises, RTOs
- **2 Start-ups** Cognitive IC and Innatera Nanosystems enabled by PRYSTINE
- **49 exploitable results**, also incl. joint exploitation e.g.
  - TTTech with Infineon (e.g. AD system design)
  - Ford Otosan with Habitus Research (ethnographic research)
- **Users' acceptance survey**:
  2535 on-line distributed questionnaires, 811responses, no compensation, English
  see Panagiotopoulos, I.; Dimitrakopoulos, G.; Keraitė, G. and Steikuniene, U. (2020). Are Consumers Ready to Adopt Highly Automated Passenger Vehicles? Results from a Cross-national Survey in Europe. In Proceedings of the VEHITS'11
- Successful **Integration** in: (i) passenger, (ii) heavy duty truck and (iii) truck with trailer vehicles
- **30** demonstrators: see https://prystine.eu/
- **94** publications, **38** print/media materials
- **8** patents filled, some more to come
- Contributions to **Standardization**,
  Safety Of the Intended Functionality (SOTIF), ISO/IEC JTC1 SC31 WG4 RF Communications and Domain and review of ISO/IEC 29167 series of crypto standards, etc.





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National Authorities:
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- PRYSTINE has received funding within the Electronic Components and Systems for European Leadership Joint Undertaking (**ECSEL JU**) in collaboration with the European Union's **H2020** Framework Programme and **National Authorities, under grant agreement n° 783190**

- **Thanks! to ALL partners** for great collaboration, valuable contributions and amazing demonstrators!

- Credits for the content of this presentation:
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  Georg Stettinger, Virtual Vehicle
  Omar Veledar, AVL
  Kaspars Ozols, EDI
  Gabrielė Keraitė, MetisBaltic

PRYSTINE will deliver
(a) fail-operational sensor-fusion framework on component level
(b) dependable embedded E/E architectures
(c) safety compliant integration of AI approaches for object recognition, scene understanding, and decision making

PRYSTINE has been accepted for funding within the Electronic Components and Systems For European Leadership Joint Undertaking in collaboration with the European Union's H2020 Framework Programme (H2020/2014-2020) and National Authorities, under grant agreement n° 783190.

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