VERIFICATION
VALIDATION
METHODS

VVMethods and SET Level – Towards a comprehensive framework for AD safety ensurance

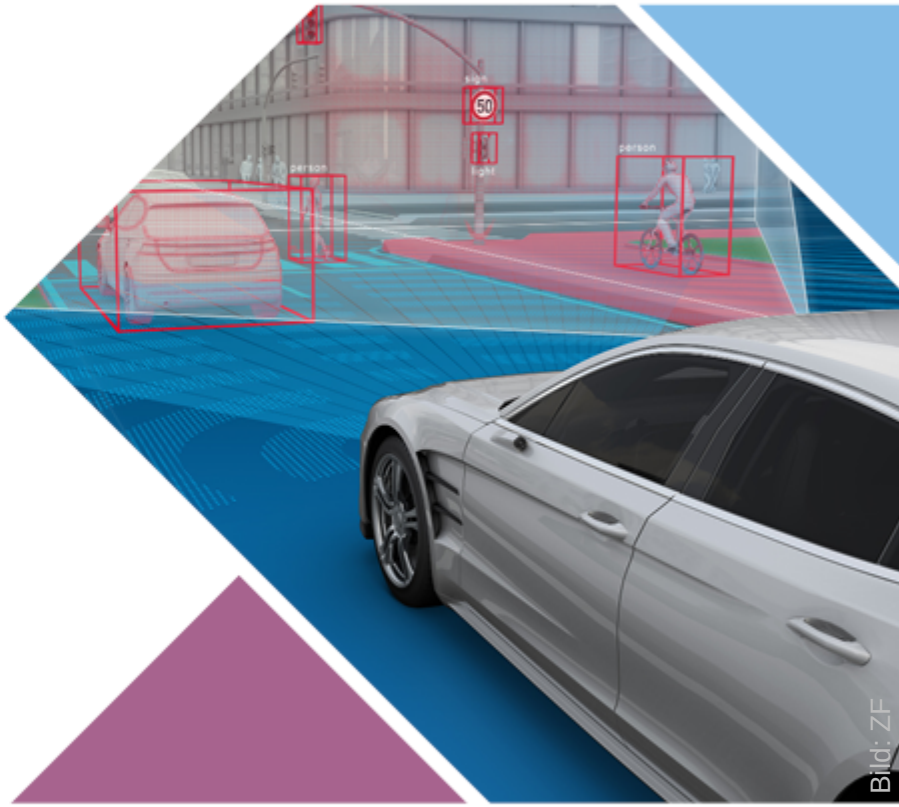


Bild: ZF

Mark Schiementz (Co-Coordinator VVM)
Christian Neurohr (Lead Criticality Analysis)
Henning Mosebach (Lead Liaison/PEGASUS Family)

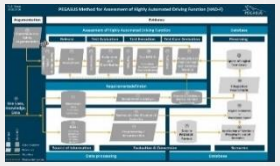
Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Set Level, VVMethods and the PEGASUS Family

The **PEGASUS Family** focuses on development / testing methods and tools for AD systems on highways and in urban environments

PEGASUS

- Scope: **Basic methodological framework**
- Use-Case: L3/4 on highways
- Partners: 17
- www.pegasusprojekt.de/en



PEGASUS

Federal Ministry for Economic Affairs and Energy

PEGASUS FAMILY

VV-Methods

- Scope: **Methods, specifications for technical assurance, toolchains**
- Use-Case: L4/5 in urban environments
- Partners: 23 partners
- Timeline: 07/2019 – 06/2023
- www.vvm-projekt.de

SET Level

- Scope: **Simulation platform, toolchains, definitions for simulation-based testing**

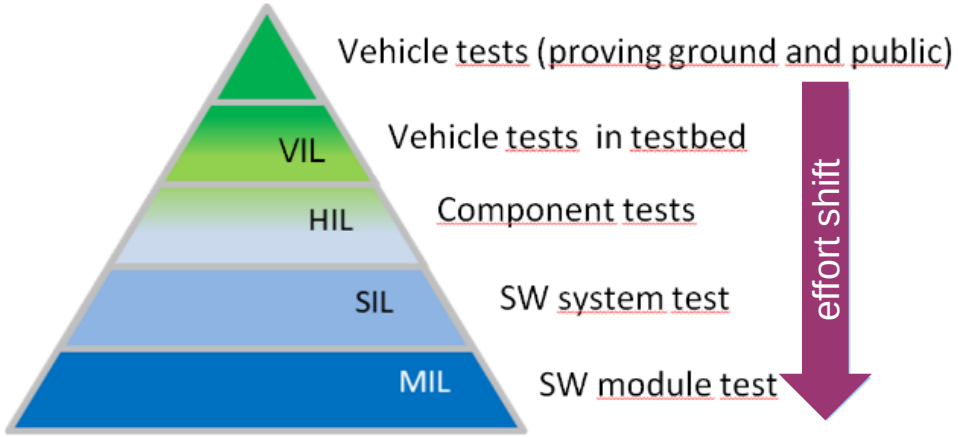
+ future projects of the PEGASUS Family

2016 — 2019

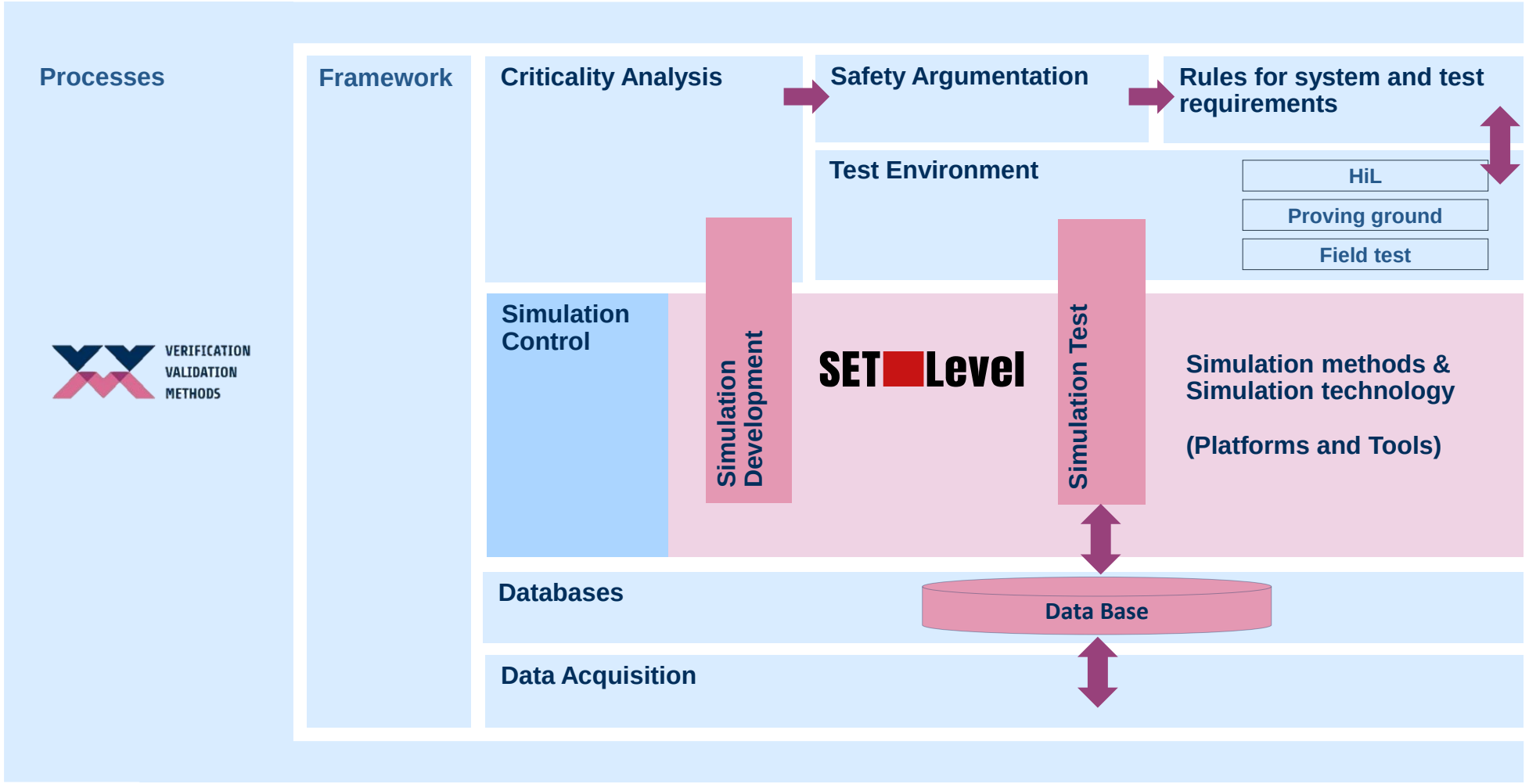
VVMethods at a glance

Development of an overall safety argumentation and validation methodology for urban automated driving safety cases

- cope with the multitude of possible traffic scenarios by a detailed analysis framework of risks.
- develop a verification and validation methodology for AD functions that covers the whole vehicle architecture and can be broken down to component level
- enables exchange between OEM and TIER by establishing common interfaces across manufacturers and digitalization of the validation chain



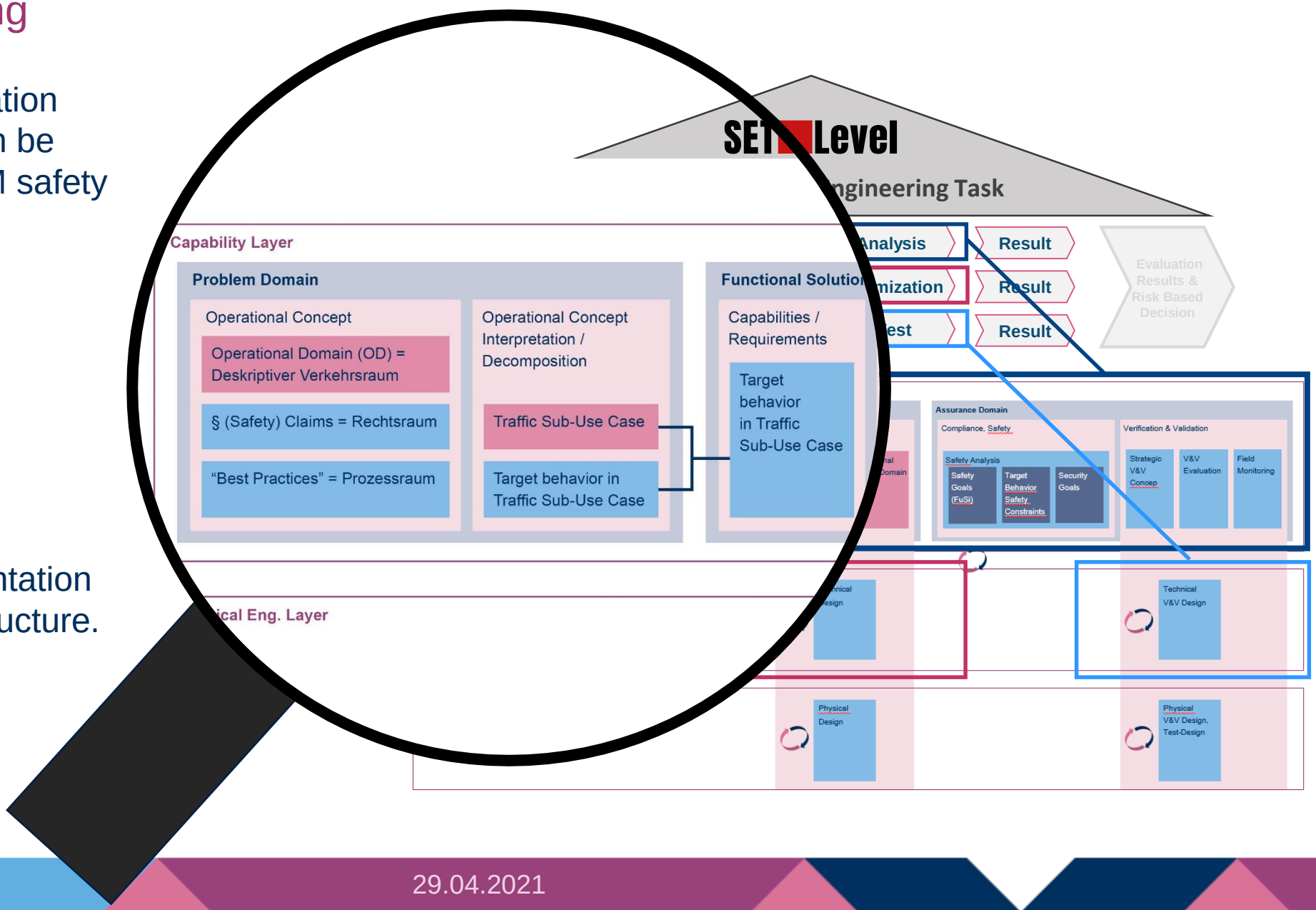
Overall Project Architecture VV Methods / Set Level



Methodological Bridge VVM – SET Level

Framework Mapping

- main focus of simulation engineering task can be assigned to the VVM safety argumentation layer structure.

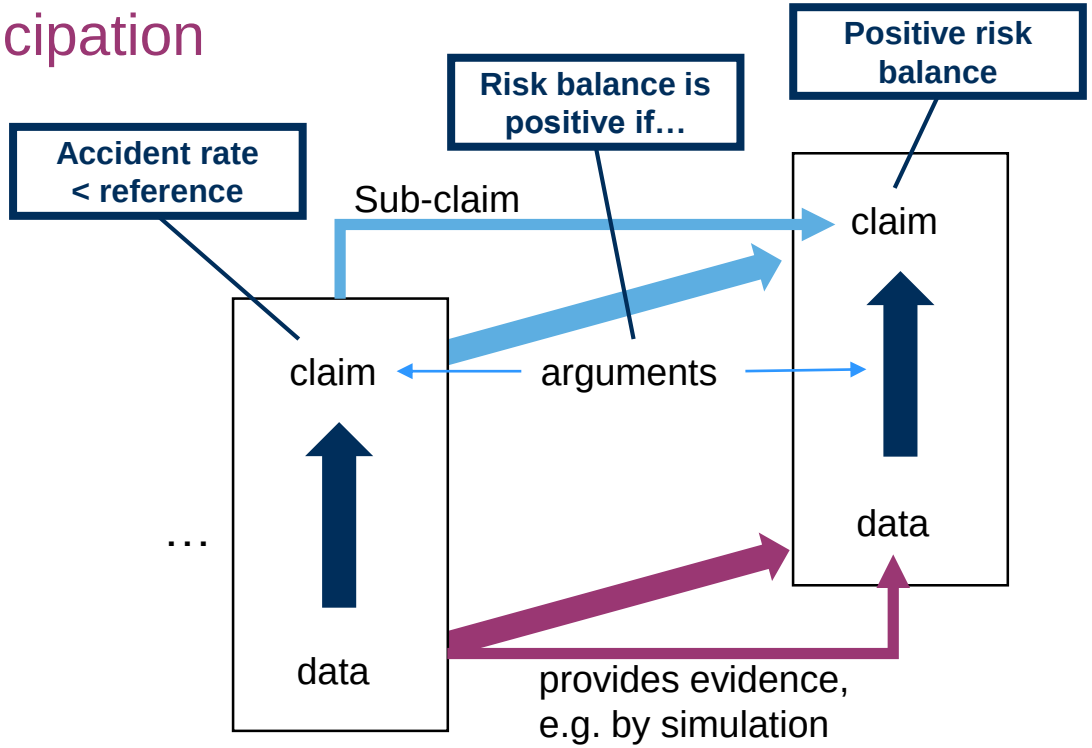


safety argumentation layer structure.

Methodological Bridge VVM – SET Level

SETL & VVM Interface Anticipation

- the requirements of a credible simulation process for the VVM argumentation structure must be defined.

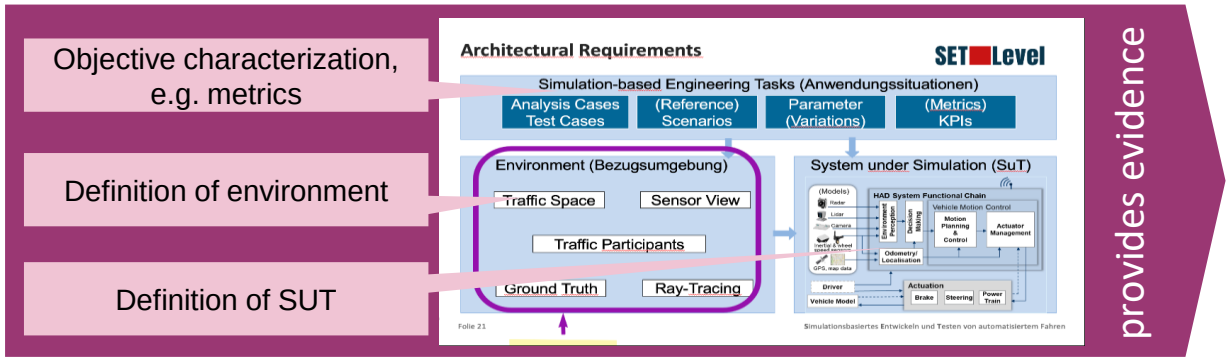


systematic decomposition of claims within agrumentation strategy

VVM safety argumentation structure

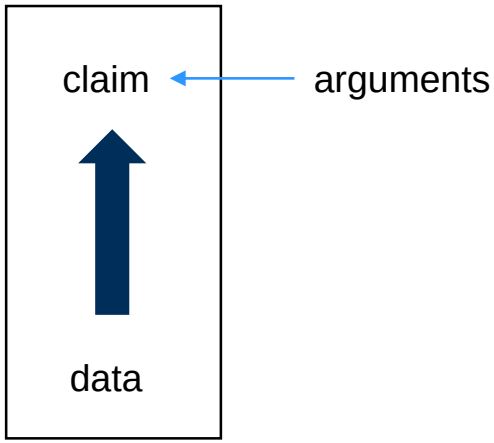
methods für obtaining evidence in order to support the VVM safety argumentation

- simulation objectives, environment and system under test are derived by claims, arguments and system data as e.g. capabilities.



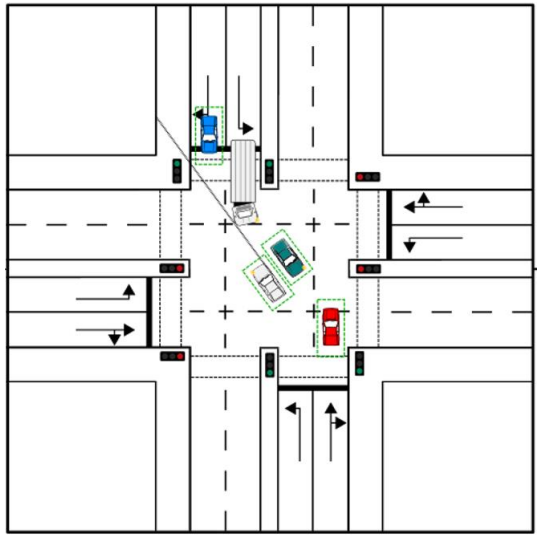
Criticality Analysis in VVM

Claim: (contribution of the VVM Criticality Analysis to the Safety Argumentation)
We **identified** and **analyzed** the relevant factors influencing criticality in the operational domain (OD).



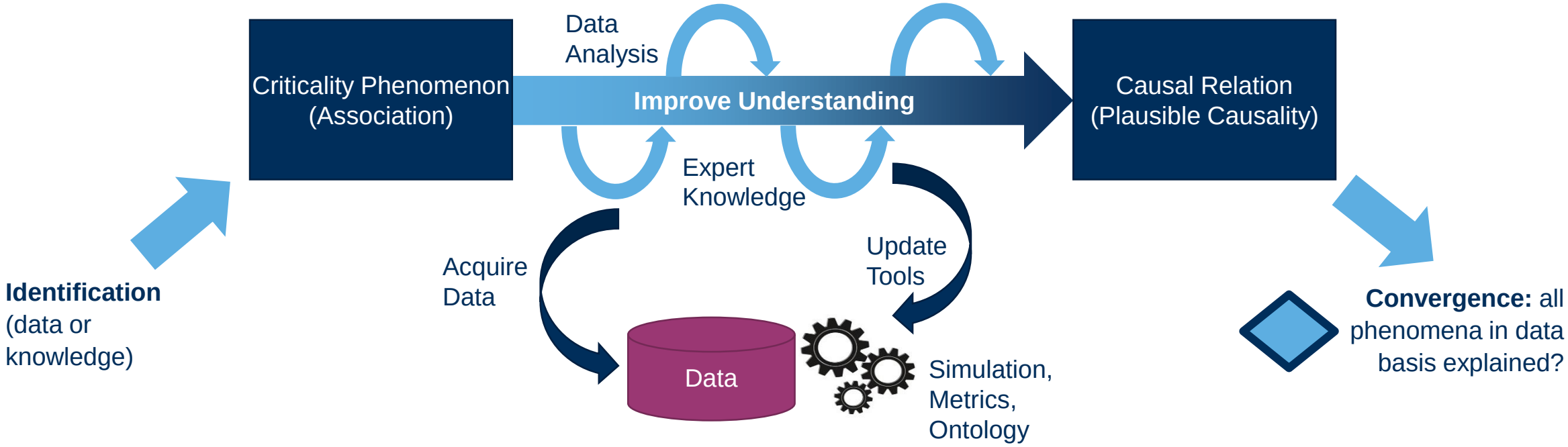
Arguments: (to substantiate the claim)
The „Criticality Analysis“ is methodically **sound** and the resulting **artefacts** are sufficiently **complete** and substantiated by **evidences**.

Artefacts: (resulting from the Criticality Analysis)
- criticality phenomena (associations with criticality)
- causal relations (plausible relations causing criticality)
- abstract scenarios (featuring phenomena and causal relations)



Tools: (employed for the Criticality Analysis)
- metrics, ontologies, simulation
- acquisition & management of knowledge and data
- data analysis (real-world & synthetic)

Criticality Analysis – Basic Concept



Assumptions:

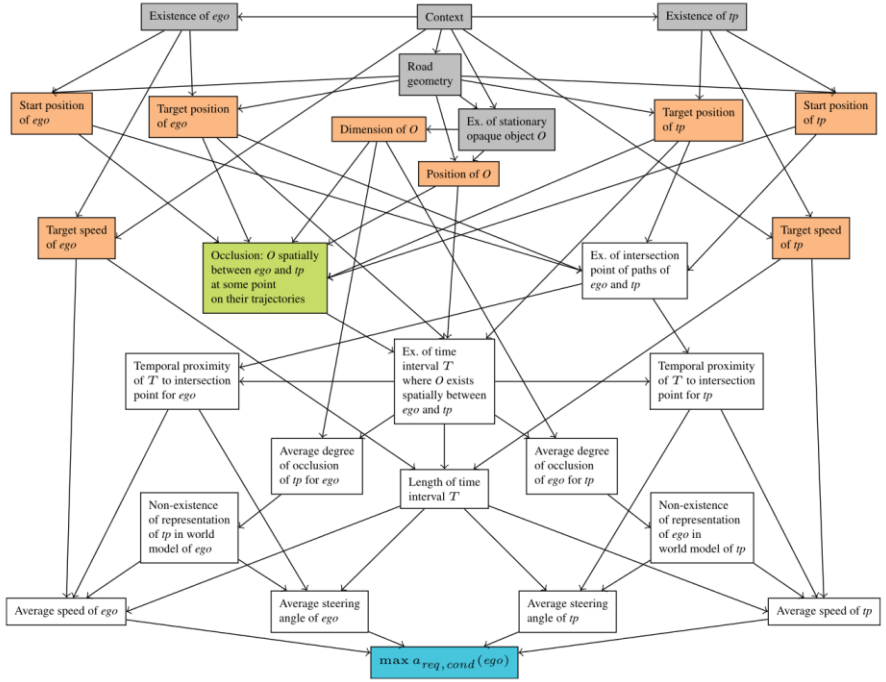
- set of criticality phenomena is limited and manageable → finiteness (of artifacts)
- relevant phenomena leave traces in growing data basis → completeness (of artifacts)

Simulation-based Analysis within the VVM Criticality Analysis

Minimal Required Functionality:

- representative sampling from large scenario classes
  - e.g. instantiation of logical scenarios using parameter variation
- execution of concrete scenarios
- evaluation of criticality metrics

→ Provided by **SET Level SUC1.**



Usage within the VVM Criticality Analysis:

- plausibilization of causal relations
  - including quantification of the effect size
- engineering, calibration and comparison of criticality metrics
- abstraction and refinement of criticality phenomena and causal relations

Plausibilization of Causal Relations using Simulation

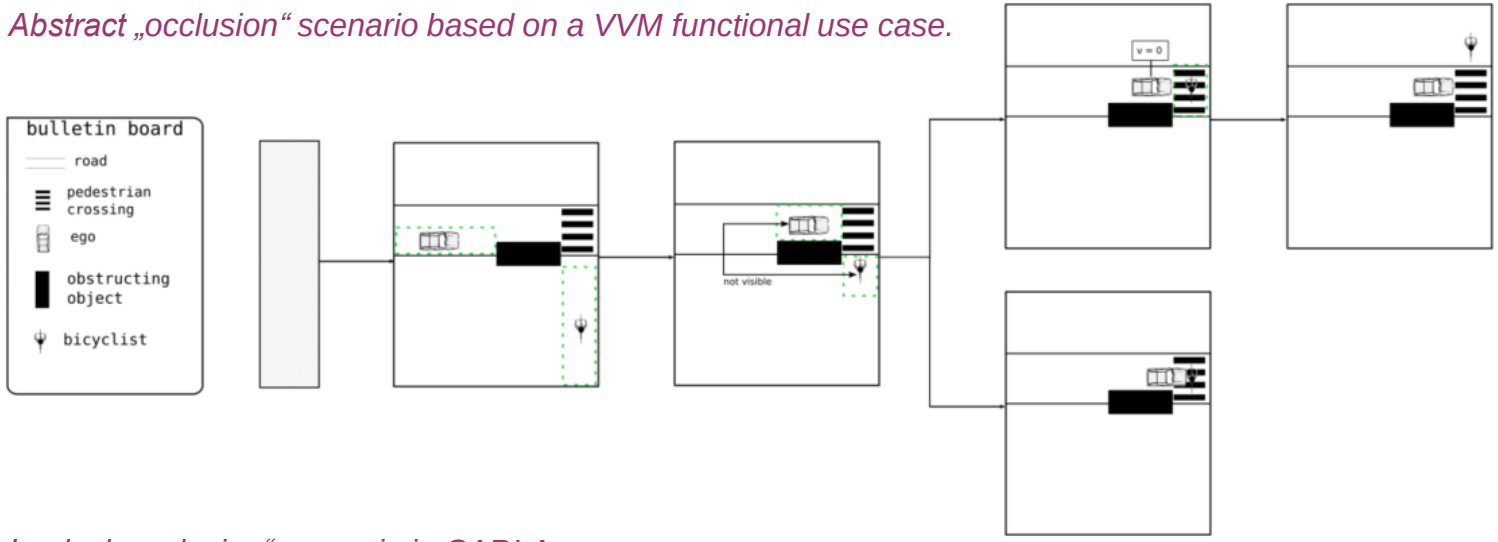
VERIFICATION VALIDATION METHODS

Task: Generate evidences for the causal relation „occlusion“

Approach:

- consider an abstract scenario with a static occlusion present
- for simulation derive a set of associated logical scenario
  - e.g. OpenPASS, CARLA, …
  - identify variation parameters via confounder analysis of causal graphs

Abstract „occlusion“ scenario based on a VVM functional use case.



Logical „occlusion“ scenario in CARLA.

Parameter	Range
ego start position (x, y)	$[-58, -33] \times [-29, -28]$
ego target position (x, y)	$[50, 55] \times [-29, -28]$
ego target speed (km/h)	$[25, 60]$
bicyclist start position (x, y)	$[31, 32] \times [3, 15]$
bicyclist target position (x, y)	$[-50, -45] \times [-34, -33]$
bicyclist target speed (km/h)	$[10, 25]$
Dimension of O (discretized as number of parking cars)	$\{0, 1, 2, 3, 4, 5, 6, 7\}$
Position of O (x, y)	$[2, 20] \times ([-35, -34] \cup [-26, -25])$

Evaluation of Criticality Metrics and Data Analysis

VERIFICATION VALIDATION METHODS

Approach (continued):

- **Generate Data Set:**
  - use variation of parameter to obtain concrete scenarios
  - execute concrete scenarios in simulation and evaluate suitable criticality metrics
- **Data Analysis:**
  - for each run evaluate whether the phenomenon was present or not
  - perform statistical analysis of the resulting data set

Correlation analysis between variables and metric

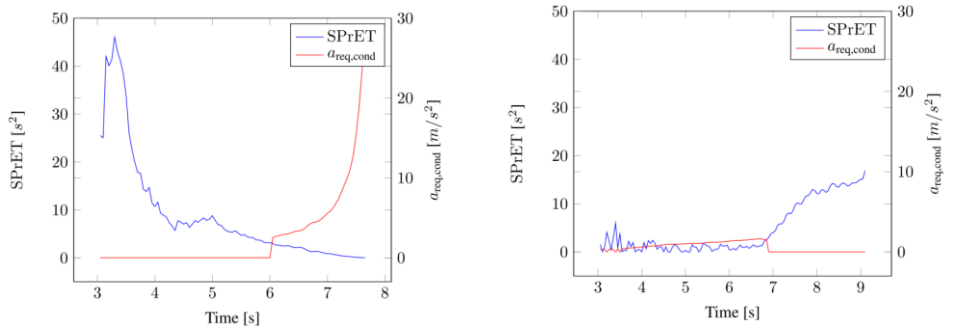
Variable	Correlation (ρ)	p-value
Occlusion	0.29	$p < 10^{-20}$
Duration of occlusion	0.26	$p < 10^{-15}$
ego starting position (x)	−0.24	$p < 10^{-14}$
bicyclist starting position (y)	−0.35	$p < 10^{-29}$
bicyclist target speed	0.42	$p < 10^{-44}$
Position of O (y)	0.20	$p < 10^{-9}$

Effect size of causality on metric:

- *Cohen's d =* ***0.93***
- *a_req,cond* ***2.9*** *times higher for „occlusion" scenarios*

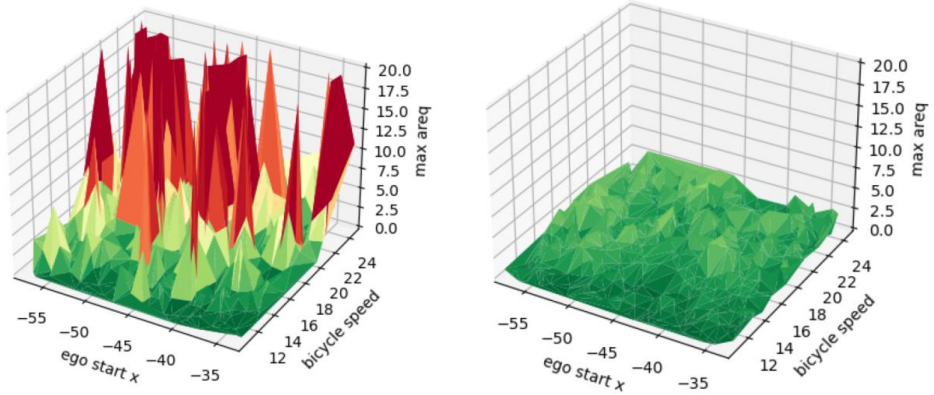
Evaluation of criticality metrics over time:

critical „occlusion" scenario vs. uncritical „non-occlusion" scenario



$3.15\ (\pm 3.10) m/s^2$ *Visualization of simulation results* $1.10\ (\pm 0.75) m/s^2$

„occlusion" scenarios vs. „non-occlusion" scenarios



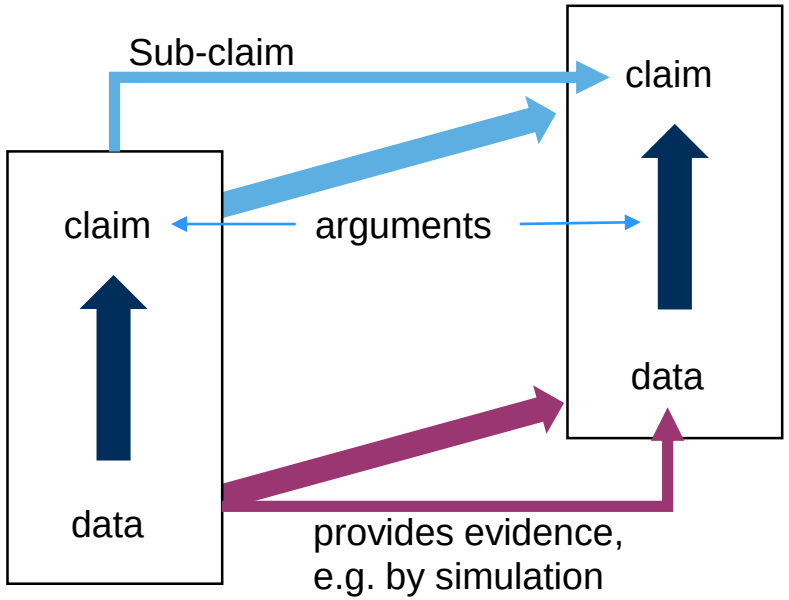
How did simulation contribute in this example?

Claim (Criticality Analysis): We **identified** and **analyzed** the relevant factors influencing criticality in the operational domain (OD).

Sub-Claim (Occlusion): We analzyed the relevant criticality phenomenon „**occlusion**“ and its effect on criticality in a urban intersection scenario.

Evidence (Simulation):

- generation of data providing evidence for the plausibility of the causal relation „occlusion“
- enabling of statistical analysis
- quantification of the effect size of „occlusion“

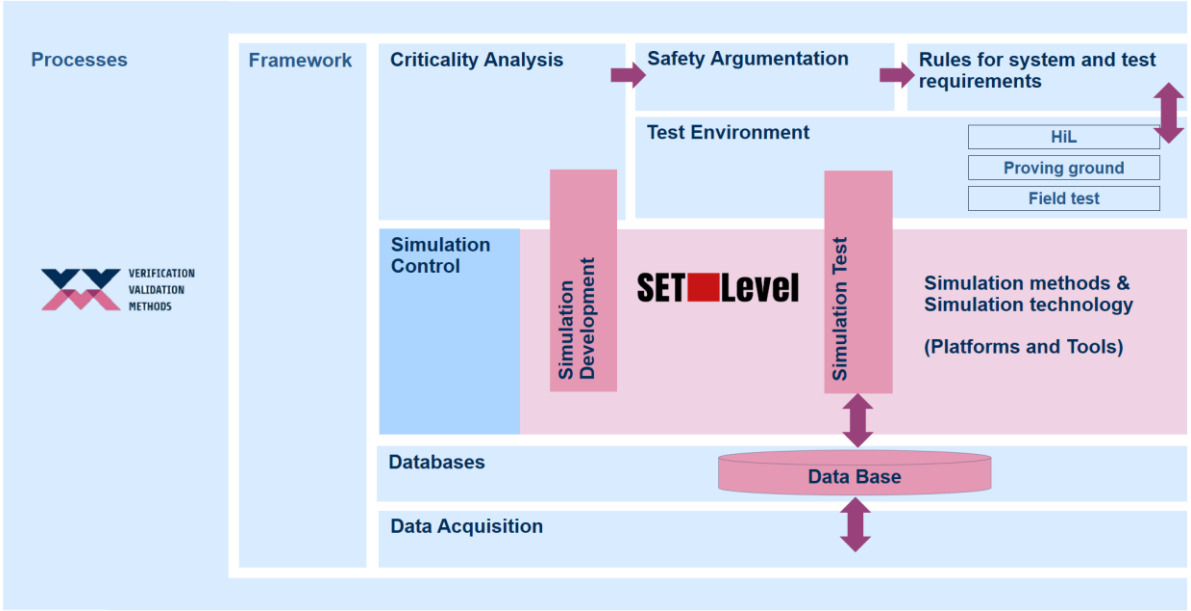


Summary

VERIFICATION VALIDATION METHODS

SET Level and VVM:

- **data generated from simulation** can be used as evidence for the **safety argumentation** within AD release
- claims, arguments and system data of the **safety argumentation** supply the simulation with **objectives, environment** and **system under test**
- the three typical engineering task domains of **SET Level** fit the AD Layer-Model of **VVM**.



Outlook:

- increasing **exchange** of **models** and **scenario descriptions** between both projects

SET Level, VVMethods and the PEGASUS Family

sharing methodologies, concepts, architectures, specifications and taxonomies

showing how transfer real world scenarios into simulations and into measurable and assessable metrics

sharing proof-of-concepts based on open standards and tool chains

PEGASUS FAMILY

Audi, BMW, Volkswagen, Mercedes-Benz, Ford, MAN, Stellantis, Opel, AVL, Continental, Valeo, ZF, Bosch, IPG Automotive, ETAS, dSPACE, TÜV SÜD, bast, FZI, OFFIS, ika, PROSTEP, DLR, Fraunhofer, Institut für Regelungstechnik IFR, FZD

- Regulation
- Standards
- Certification
- Communities

Meeting the PEGASUS Family…

- …on our project and networking websites
- …in several international working groups in standardization and regulation
- …on bilateral exchange meetings
- …on conferences and workshops, e.g.

https://setlevel.de

https://www.vvm-projekt.de

www.pegasusprojekt.de

www.transfer-project-exchange.com

e.g. with SAKURA (JPN), HEADSTART (EU), NHTSA (US), PEGASUS network (INT), VIVALDI (GER), ARCADE (EU), ADScene (FR)…

SET Level Mid-Term presentation 29.04.

Automated Road Transport Symposium ARTS21 (AVS21) 12.07.

ITS World 2021 (Hamburg) Session (Tools and methods) 11.10.

SIP-adus WS (Tokyo) 09.11.-11.11.

Jan 21 | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dez 21

VERIFICATION
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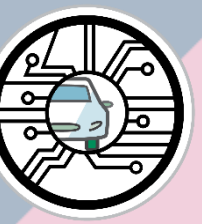
Thank you for your attention!

Henning Mosebach, Mark Schiementz, *Roland Galbas, Christian Neurohr



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