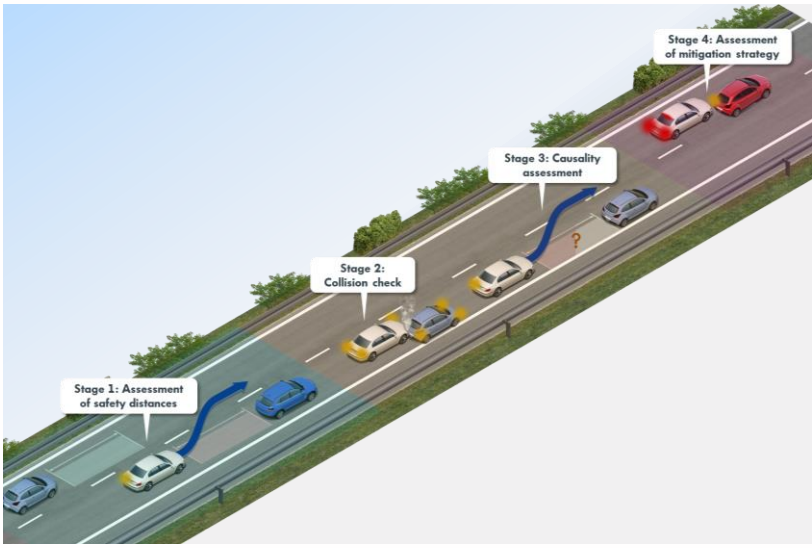
GOAL – Boot No. 28

SAFETY STATEMENT

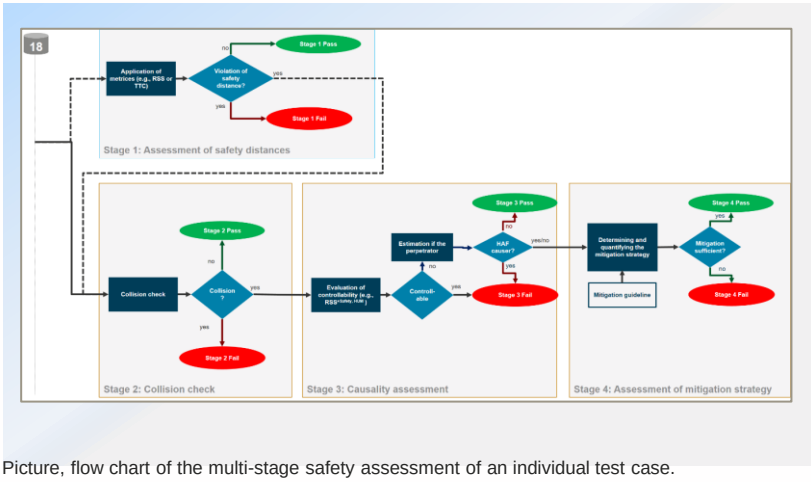
PEGASUS

PEGASUS Behavioral Safety Assessment assesses the HAD-F in individual test-cases and proposes an extrapolation approach to derive more expressive safety statements.

- Each test-case is assessed in four stages by different criteria.
- In PEGASUS these criteria are (1) keeping appropriate safety distances, (2) not crashing with other objects or obstacles, (3) not causing a collisions and (4), if possible, mitigating unavoidable collisions.
- During the multi-stage safety assessment, for each of these criteria, it is evaluated if the HAD-F complied with it or not.
- After evaluating all stages it is determined if the test-case is passed or failed.
- Conclusion on the HAD-F's safety can be drawn from the individual test-case results or by extrapolating these results to their associated logical scenario.



Picture, visualization of the multi-stage safety assessment in typical highway scenarios. The automated vehicle is white. All stages are applied to each time-step of the test-case.



Picture, flow chart of the multi-stage safety assessment of an individual test case.

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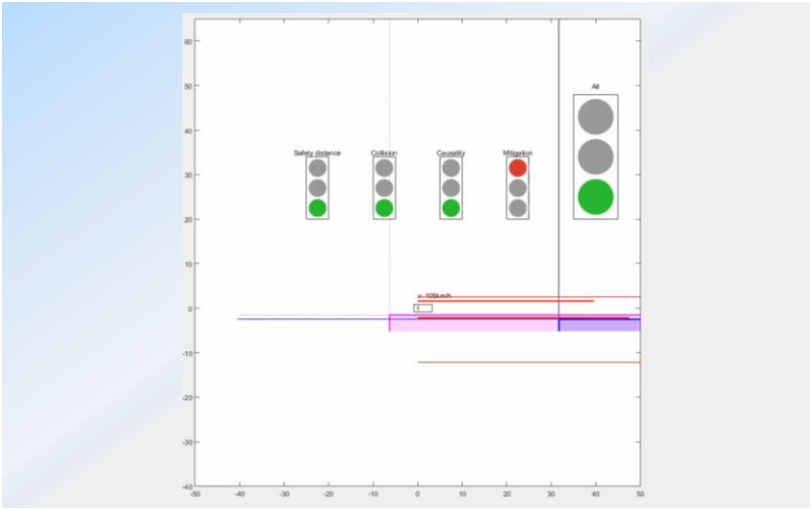
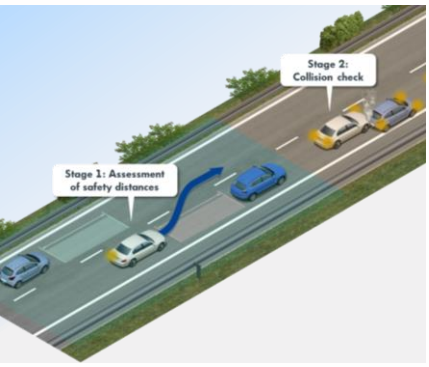
PEGASUS

Predictive risk minimizing behavior is crucial to the HAD-F's safety. Assessing collisions is a basic indicator for non-safe driving behavior.

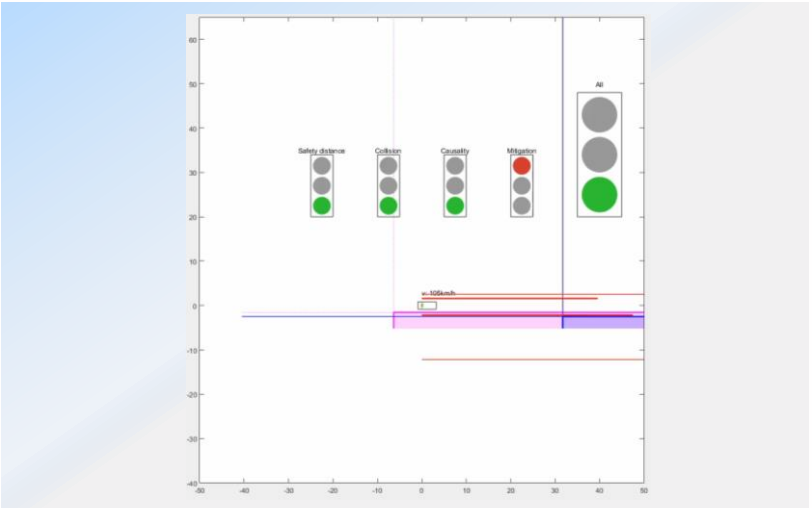
- Real world crash data are one source for test-cases assessed in the Behavioral Safety Assessment.
- In these cases the HAD-F's behavior can be compared to the human drivers response.



Video, re-simulation of a real world crash, where a merging car violates appropriate safety distances. The ego-vehicle (in this case a human driver) responses with a late braking intervention.



Picture, stages 1 and 2.



Video, same real world crash, where the ego-vehicle is now an automated car. As for the human driver the mitigation attempt is too late to avoid a collision.

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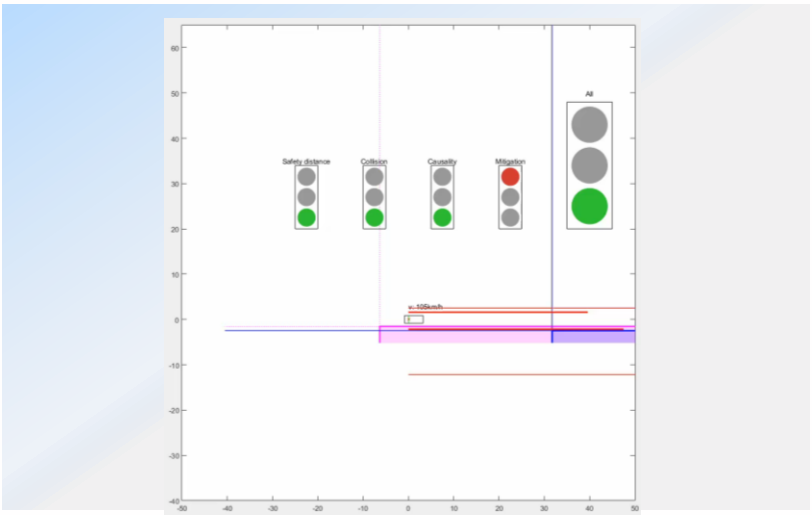
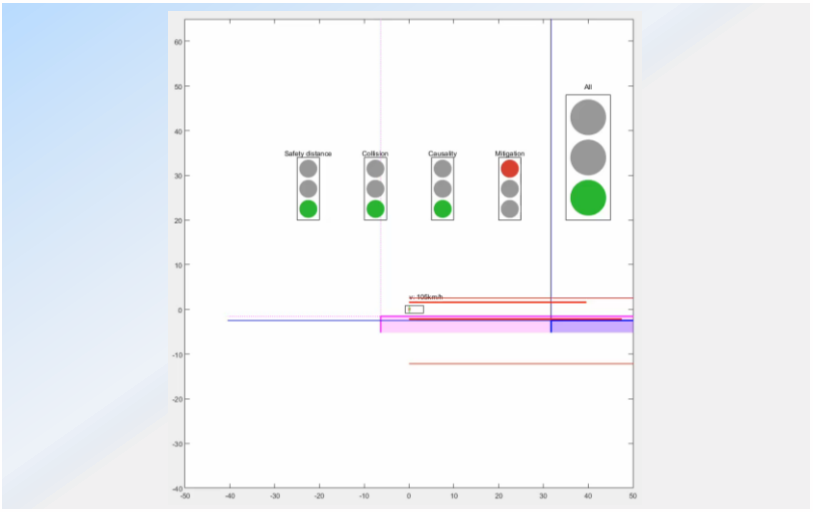
Knowing who caused a collision and if it would have been preventable is important to assess the HAD-F's safety. Additionally, the mitigation behavior is crucial as it directly contributes to the overall risk minimization goal.

- The intention to mitigate and to avoid a crash if physically possible is one of the most important safety criteria for the HAD-F's safety.
- The mitigation strategy is assessed no matter if the HAD-F caused the collision or not.



Video, same real world crash, where the ego-vehicle is now an automated car. In this simulation, the automated vehicle brakes earlier and thus avoids the crash.

Picture, stages 3 and 4.



Video, same real world crash, where the ego-vehicle is now an automated car. In this simulation, the automated vehicle does not show an intention to avoid or mitigate the crash.

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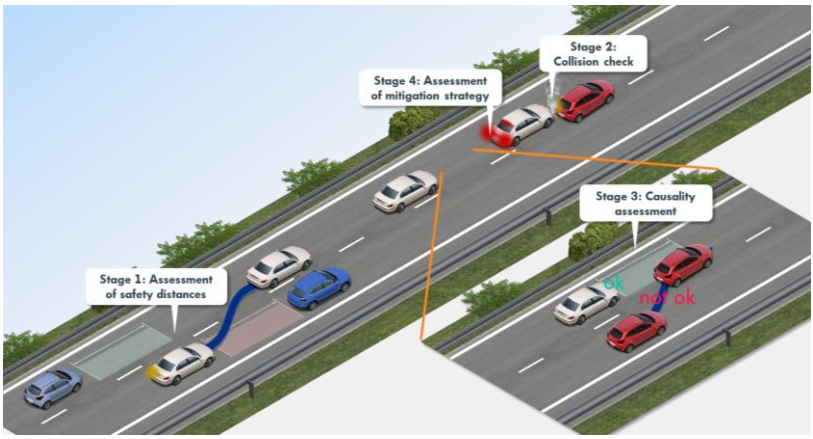
PEGASUS

The overall rating of a test-case is derived by aggregating the time-discrete results of the multiple stages.

- The contribution of the different stages to the overall test-case result differs depending on their character.
- Failing in stage 1 and 2 may still lead to an overall pass if stage 3 and 4 are passed.
- Failing stage 1 but passing stages 2-4 may lead to a pass-. This is a way to incorporate time-dependent effects.
- Failing stages 3 and 4 is considered a non-safe behavior.

Overall Result	Safety distances (Stage 1)	Collision (Stage 2)	Causality (Stage 3)	Mitigation Strategy (Stage 4)
FAIL	fail	fail	-	fail
PASS-	fail	pass	-	-
PASS/FAIL	fail	fail	pass/fail	pass
PASS	pass	-	-	-

Picture, example of overall test-case rating based on the 4 proposed stages. 0 and 1 are indicating if a stage is failed or passed, respectively.



Picture, application the different safety criteria over time.

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The safety rating of individual test cases allow to compare different HAD-F releases. An extrapolation of the individual results to e.g., logical scenarios requires many additional information.

		Input for Behavioral Safety Assessment		Result
5	○	**Medical severity or probability of a fatal crash k_d in each e_s**	○	Probability of a fatal crash $\left(\frac{K_d}{km}\right)$
4	○	**Share of critical scenarios in F_a.**	○	Frequency $(\frac{\mathrm{e_S}}{\mathrm{km}})$ of inaceptable scenarios e_s.
3	○	**Share of the critical traffic situation of an average yearly driving distance F_a. Represented by the semi-concrete/logical scenario under test.**	○	Ratio [%] by which the HAD-F solves the critical situations contained in $\mathrm{F_a}$.
2	○	**Importance of the test-case π_i^R [%] in the semi-concrete/logical scenario under test, with $\sum_{i=0}^{N_R} \pi_i^R = 1$. N_R is the total number of test-cases representing the scenario.**	○	Ratio [%] of passing the scenario under test
1	○	**Results for the 4 stages of a single test-case**	○	Overall result of the test-case as in Figure 31

Table, example for required information for test-case extrapolation. Row 1 allows for comparison of two HAD-F Releases. Row (2-4) contain more expressive results. However, the additionally required information may only be available after intensive real world testing. Row (5) contains the result aimed for in PEGASUS. However, estimating the probability of a fatal crash is beyond the state of the art and thus obtaining this results requires further intensive research.

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