P-IT-001

Simulation-based evaluation of the impact of perception sensor configuration on integrated safety of automated vehicle

Jinsil Lee and Ralf Sturm (Institute of Vehicle Concepts)

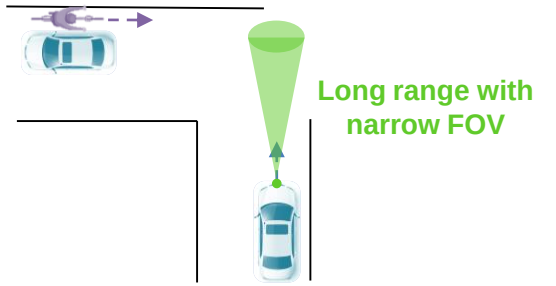
German Aerospace Center (DLR), Stuttgart, Germany

Overview of Research

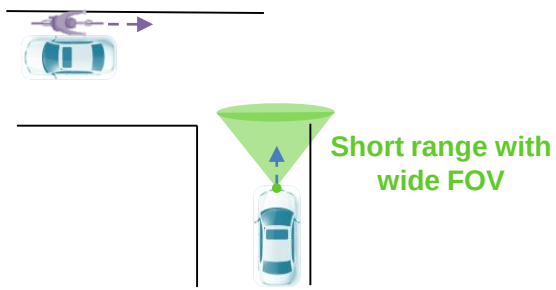
Sensor Set (a front radar)

Sensor specification
(max. Range & Field of View)

(Sensor set 1)



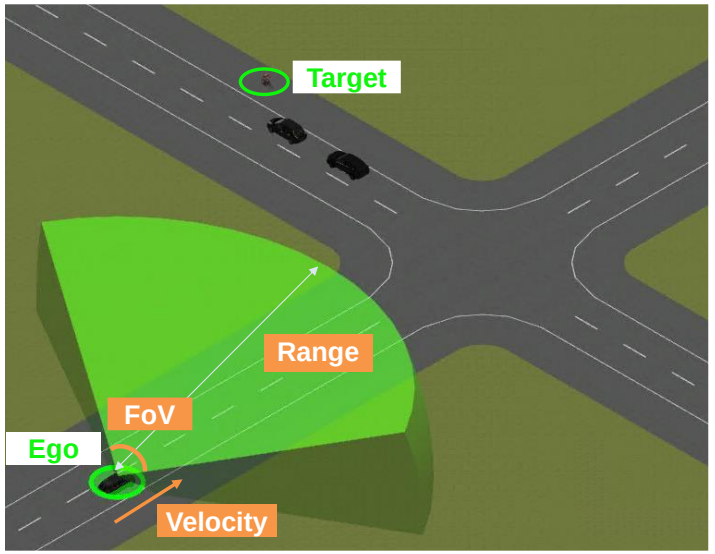
(Sensor set n)



Simulation

Autonomous driving simulations under different sensor sets

EURO NCAP scenario (CBFA)



Integrated Safety Evaluation

Quantify safety measures

Active Safety: Avoiding accidents

Analyze perception capability in terms of ***area of detection***

Passive Safety: Reducing collision impacts

Analyze the impact of sensor's perception capability with respect to ***possible collision risk***

Potential collision impacts

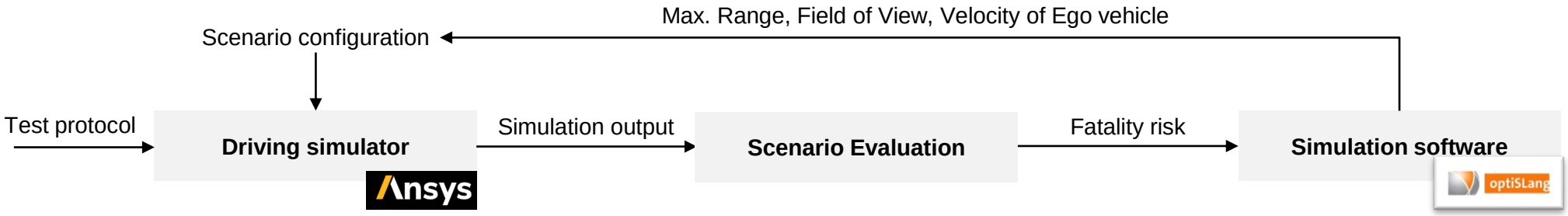
Sensor outputs

Evaluate integrated safety considering perception capability and its impact on possible collision risk

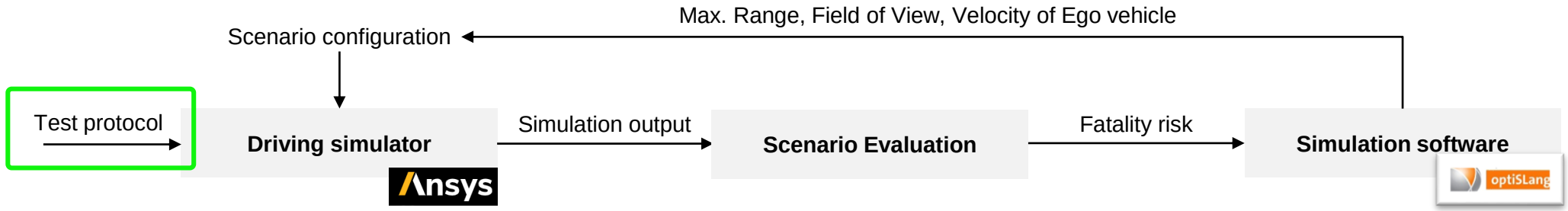
Feedback loop

Evaluation of the impact of perception sensor configuration on integrated safety

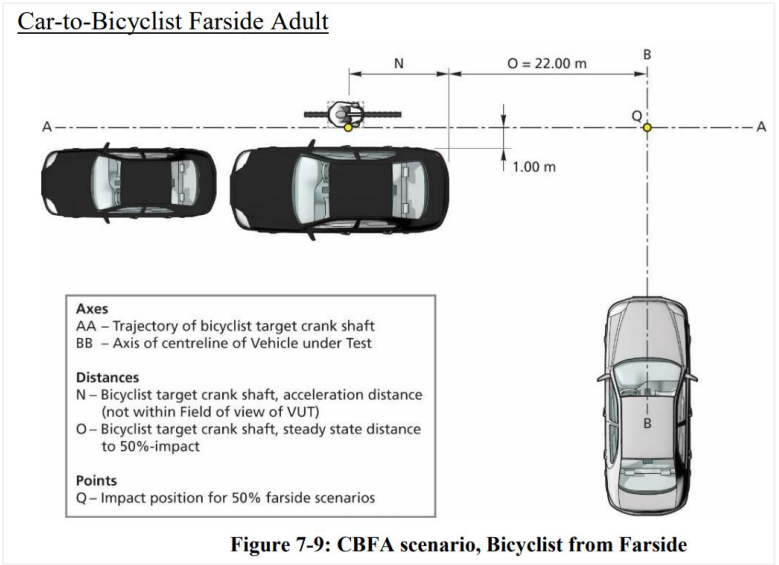
Simulation Process Chain



Simulation Process Chain

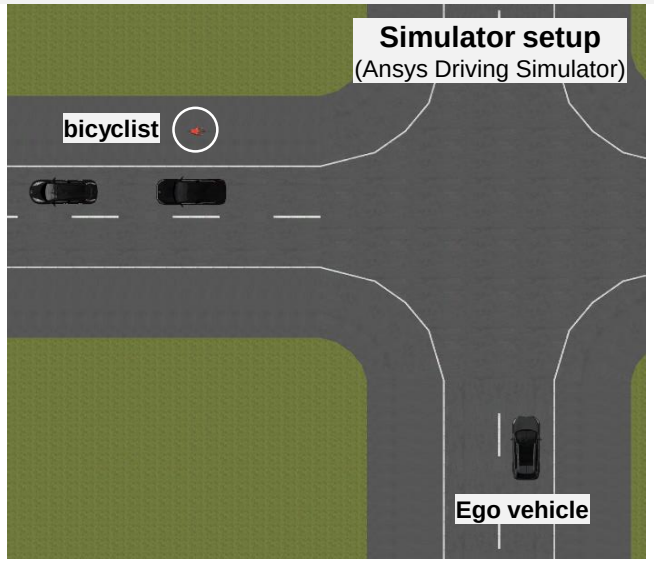


Test protocol: Euro NCAP CBFA

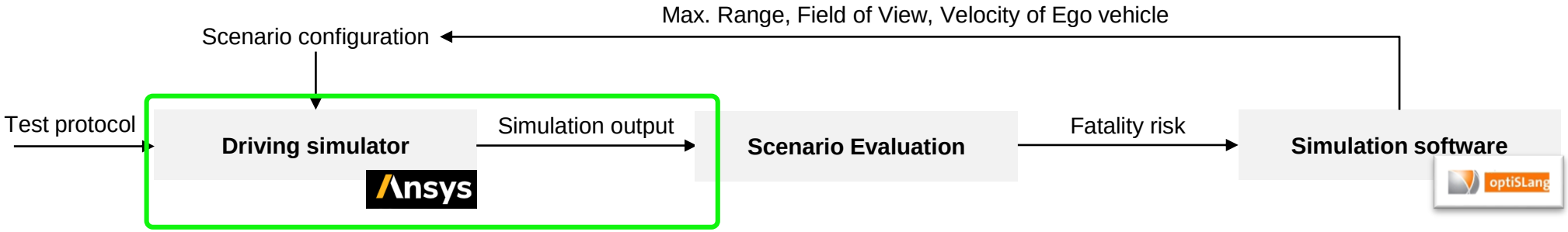


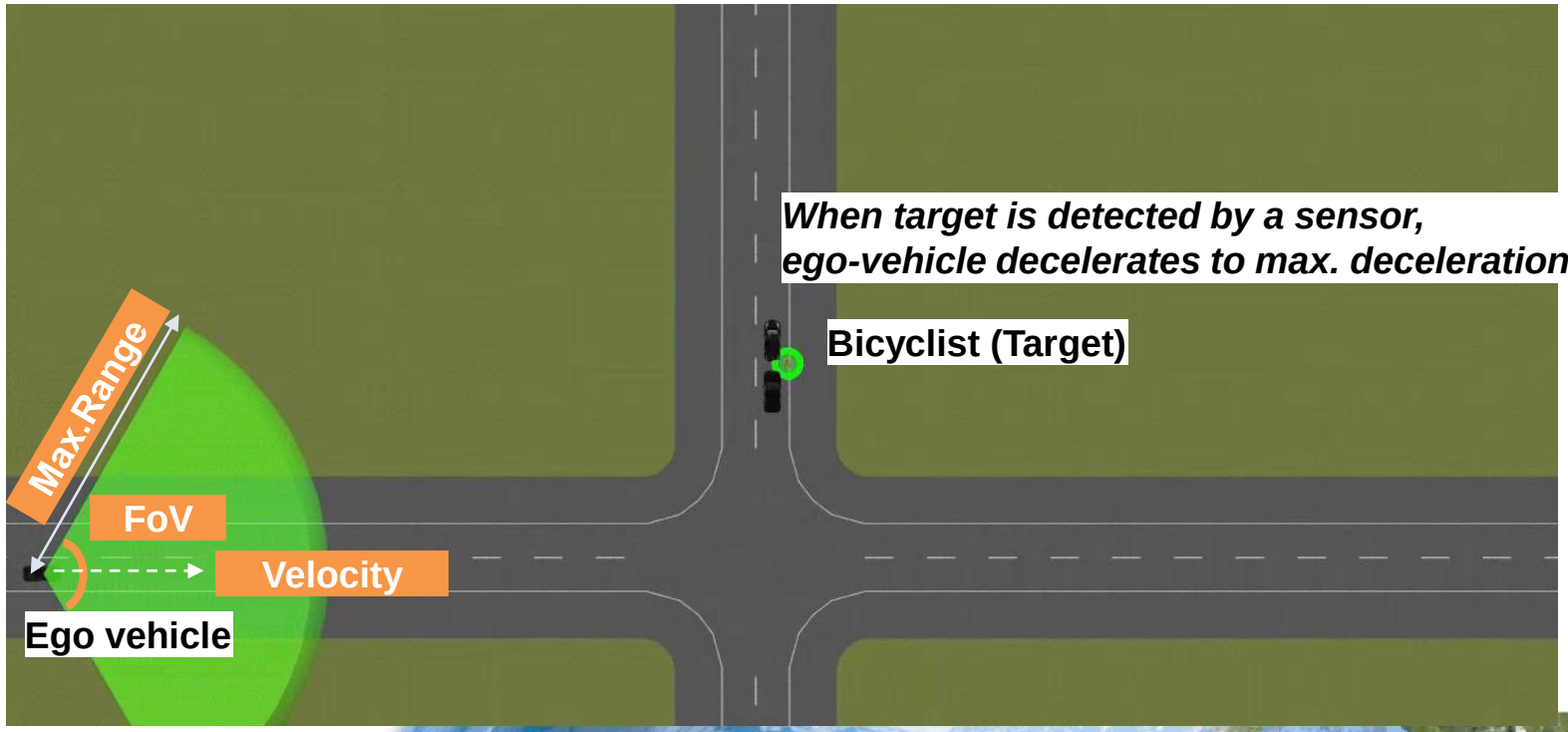
[©EURO NCAP, 2019]

Generate a simulation scenario within the simulator

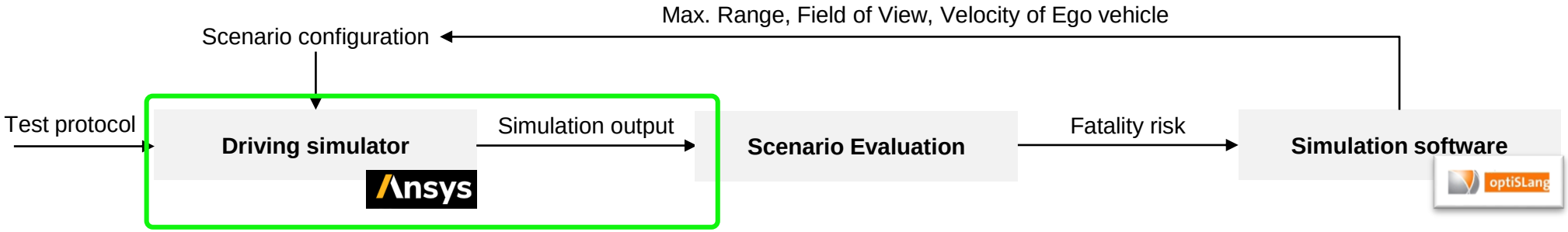


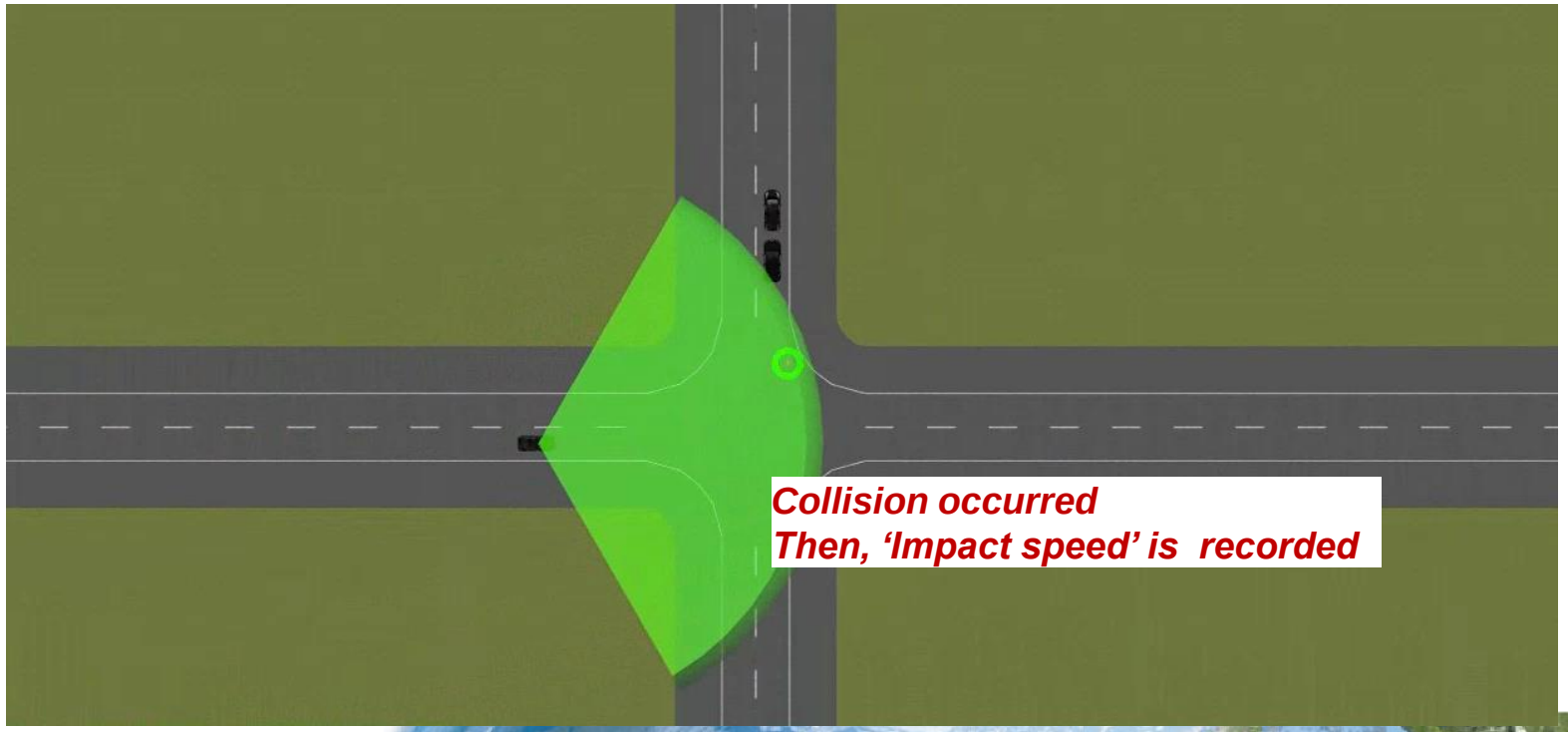
Simulation Process Chain



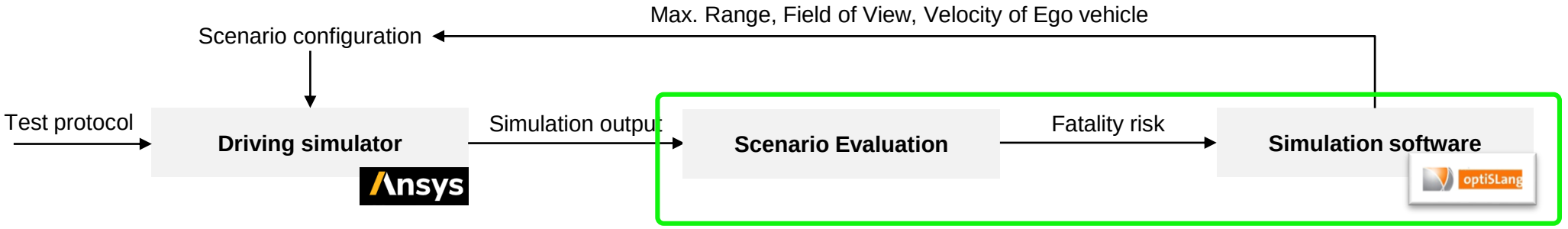


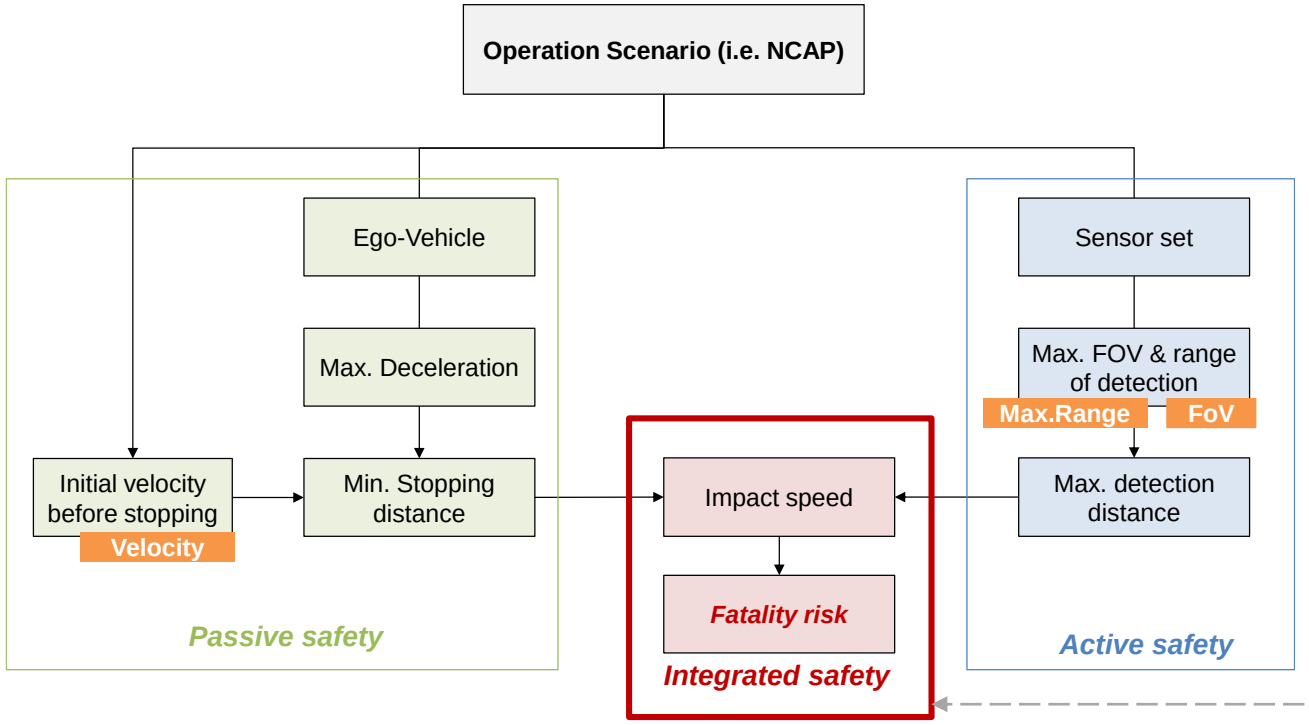
Simulation Process Chain





Simulation Process Chain





- *Fatality risk as a function of impact speed*
  [D.C. Richards, 2010]

$$Fatality\ risk = \frac{1}{1 + e^{6.9 - 0.090 \cdot Impact\ speed}}$$

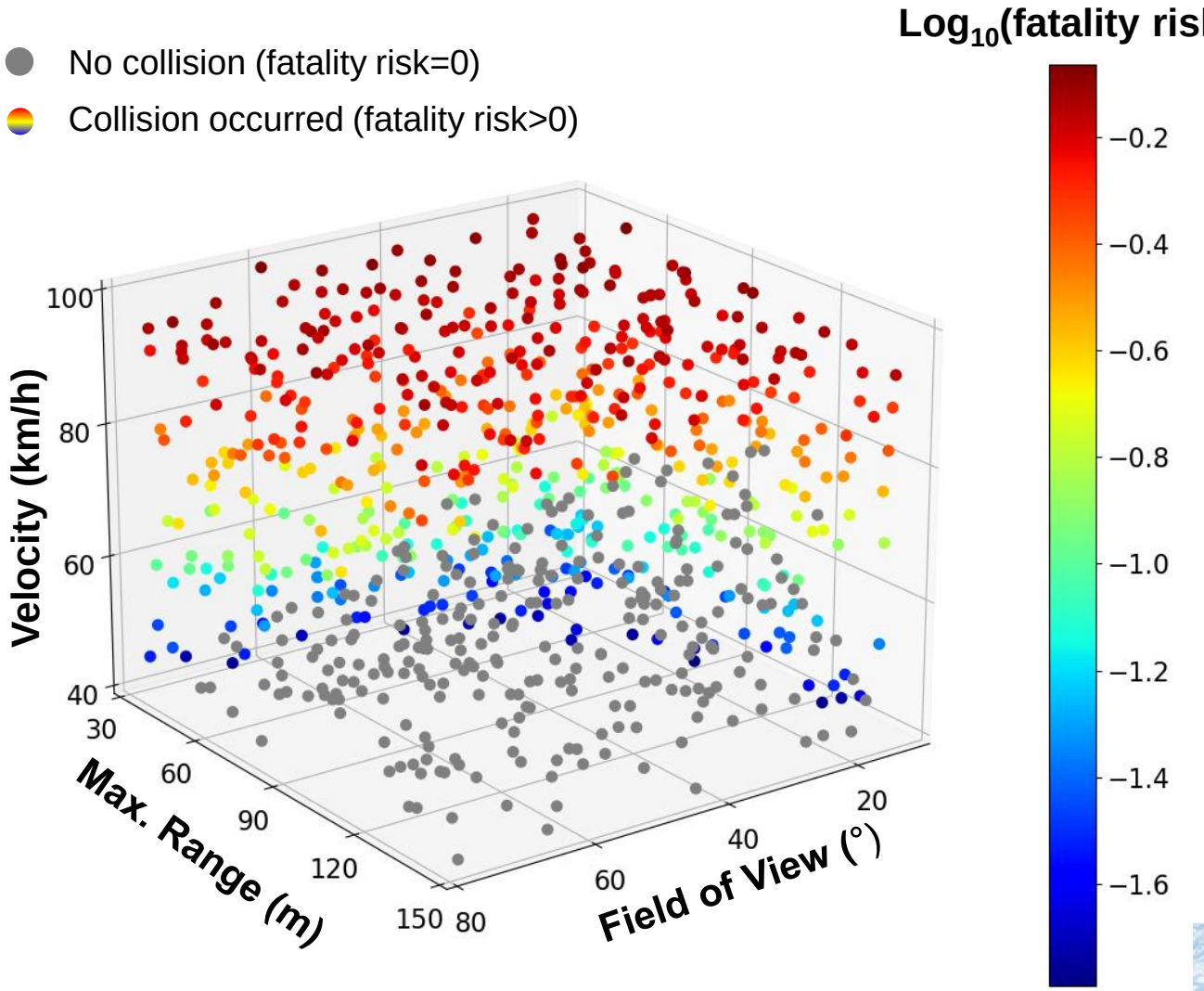
Richards, DC. “Relationship between Speed and Risk of Fatal Injury: Pedestrians and Car Occupants.” Transport Research Laboratory, Department of Transport, London, UK: 2010.

▪Simulation results & an example use-case

Simulation results: fatality risk for different sensor configurations

No collision (fatality risk=0)

Collision occurred (fatality risk>0)

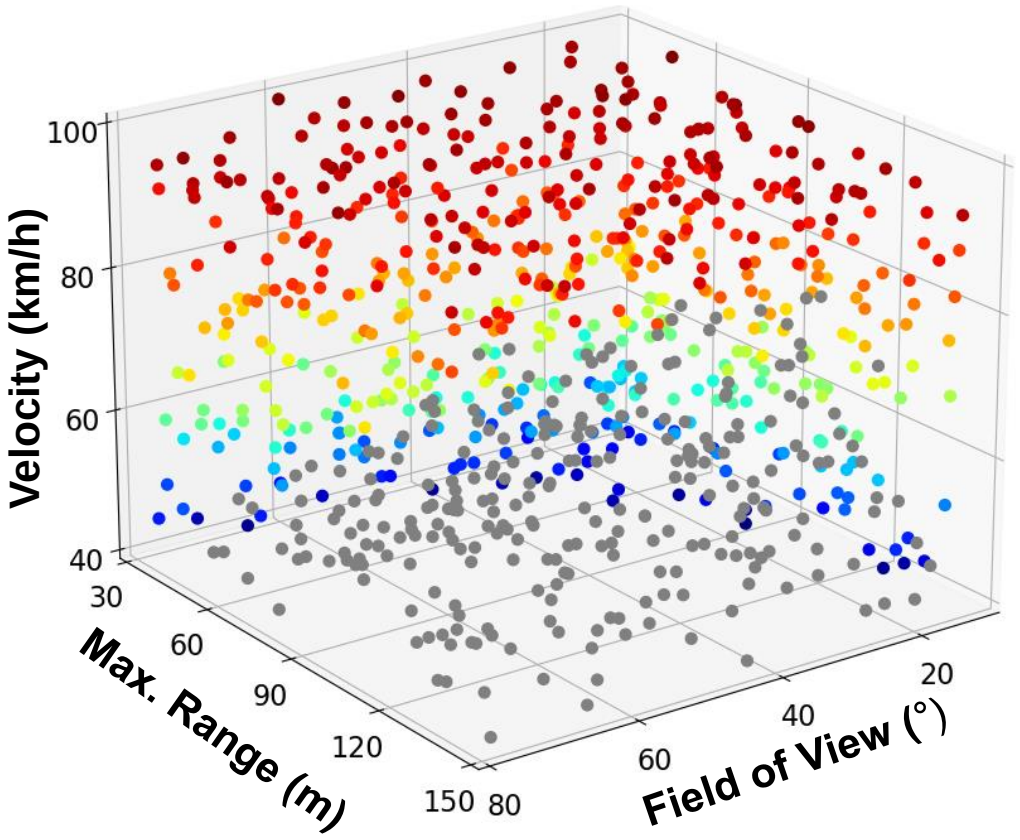


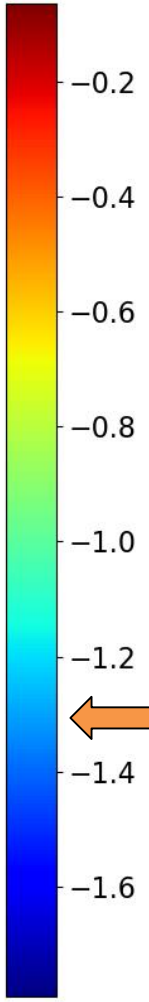
[Variable range used for the simulation]

Variables	Range
Max. Range	(30m, 150m)
Field of View	(10°, 80°)
Velocity (Ego Veh.)	(40km/h, 100km/h)
# of simulations	800

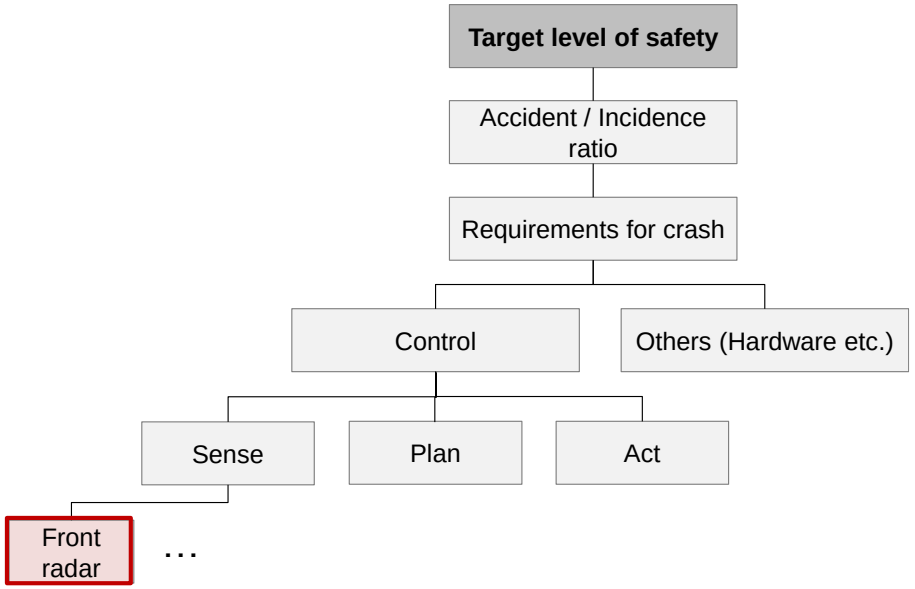
Safety requirement for a front radar

- No collision (fatality risk=0)
- Collision occurred (fatality risk>0)





Fault-tree of an automated vehicle operation



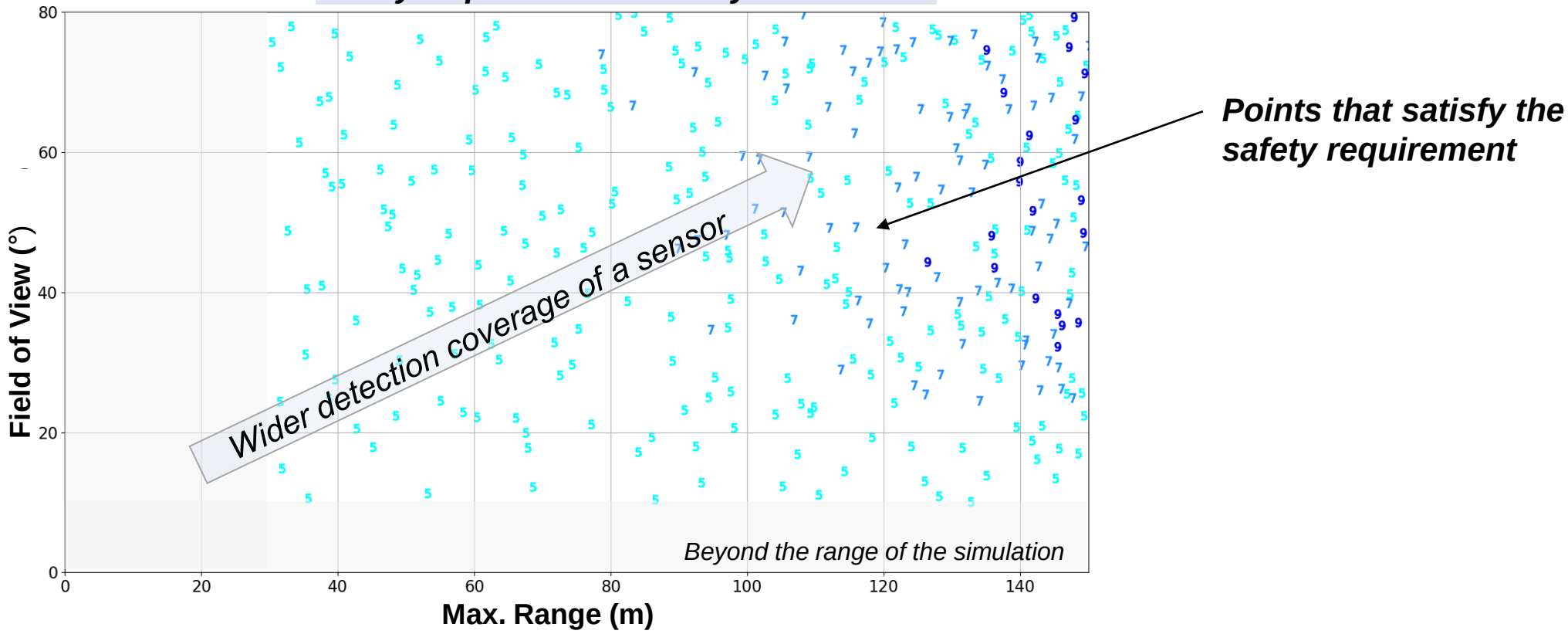
Safety requirement for a front radar

Safety risk requirement=0.05 (as an example)

Sensor configuration in terms of integrated safety

- Allowable sensor configurations given the safety requirement

Safety requirement: Fatality risk < 0.05

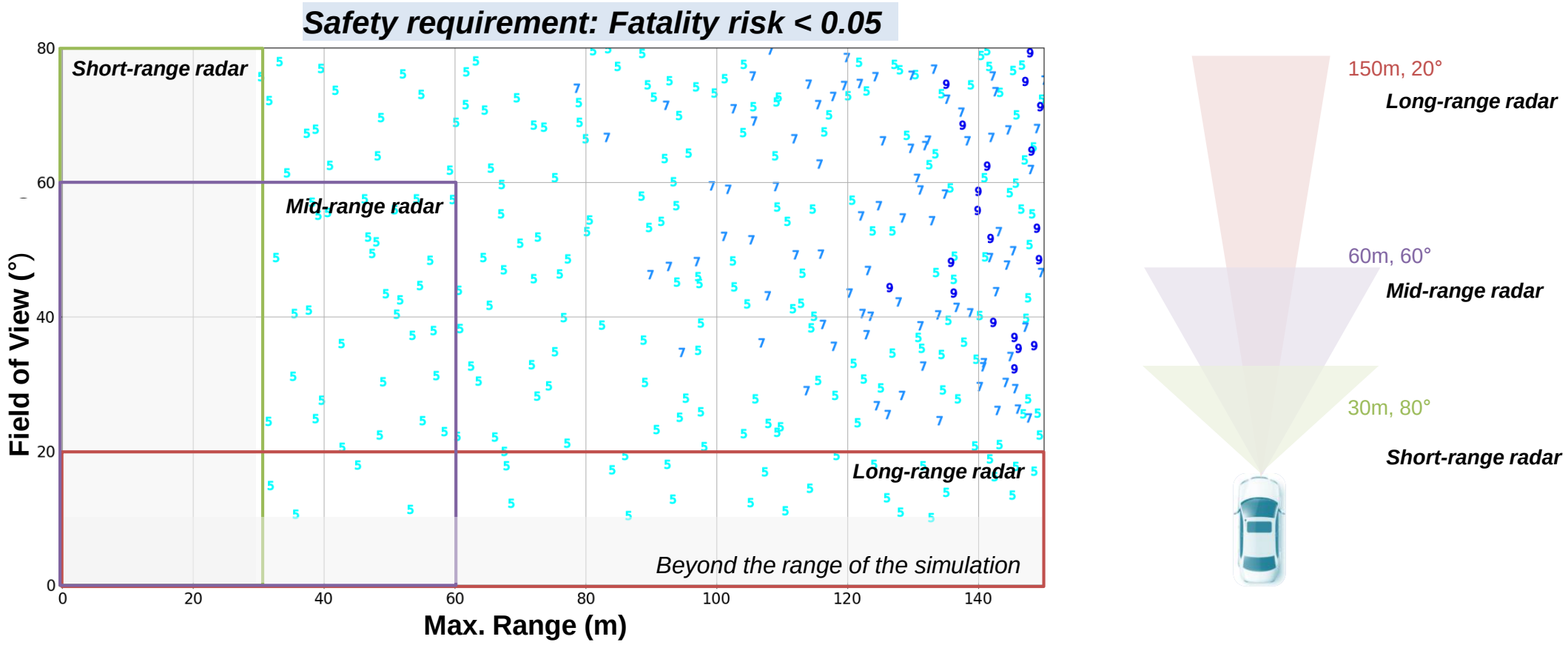


Points that satisfy the safety requirement

5 **Velocity: 40 - 50 km/h** **7** **Velocity: 50 - 70 km/h** **9** **Velocity: 70 - 90 km/h**

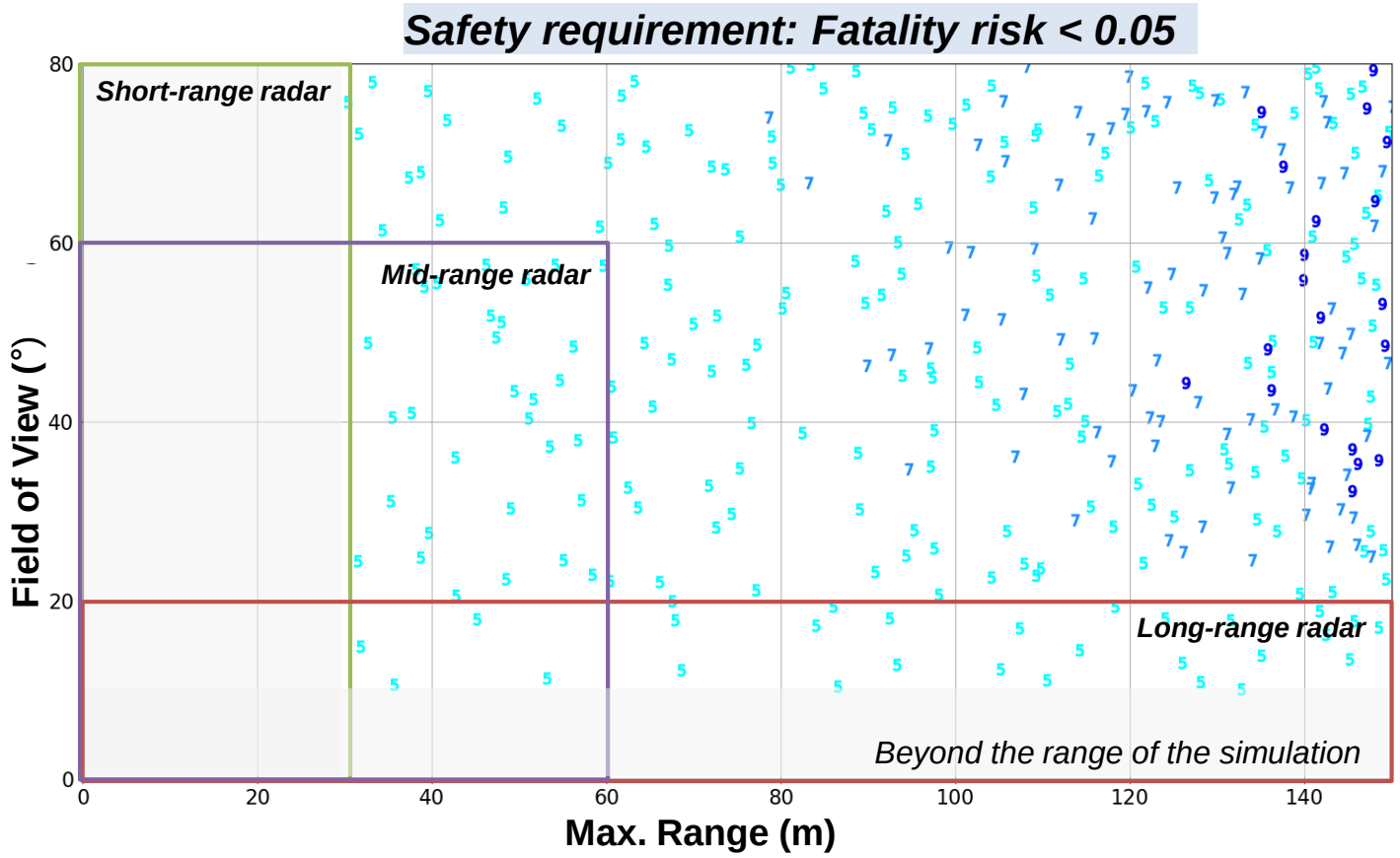
Sensor configuration in terms of integrated safety

- Typical types of radar sensors



Sensor configuration in terms of integrated safety

- With a single radar



5 Velocity: 40 - 50 km/h 7 Velocity: 50 - 70 km/h 9 Velocity: 70 - 90 km/h

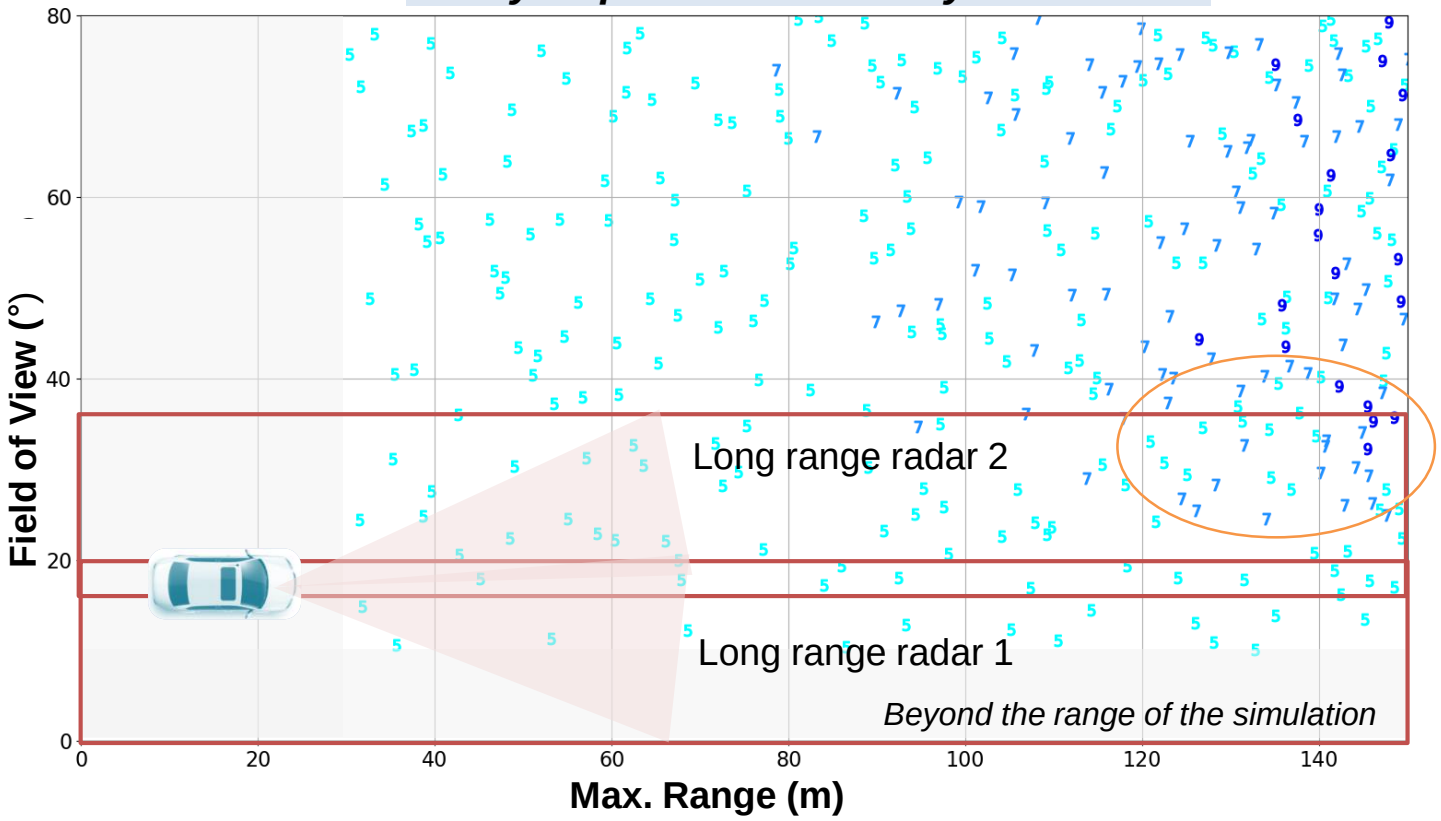
Using a *single radar* *(regardless of radar type)***,**

the safety requirement (fatality risk < 0.05) is met when ego-vehicle velocity is less than 50km/h

Sensor configuration in terms of integrated safety

- Direction for supplementing sensor configuration to meet the safety requirement

Safety requirement: Fatality risk < 0.05



To meet the safety requirement from a vehicle with velocity *greater than 50km/h*,

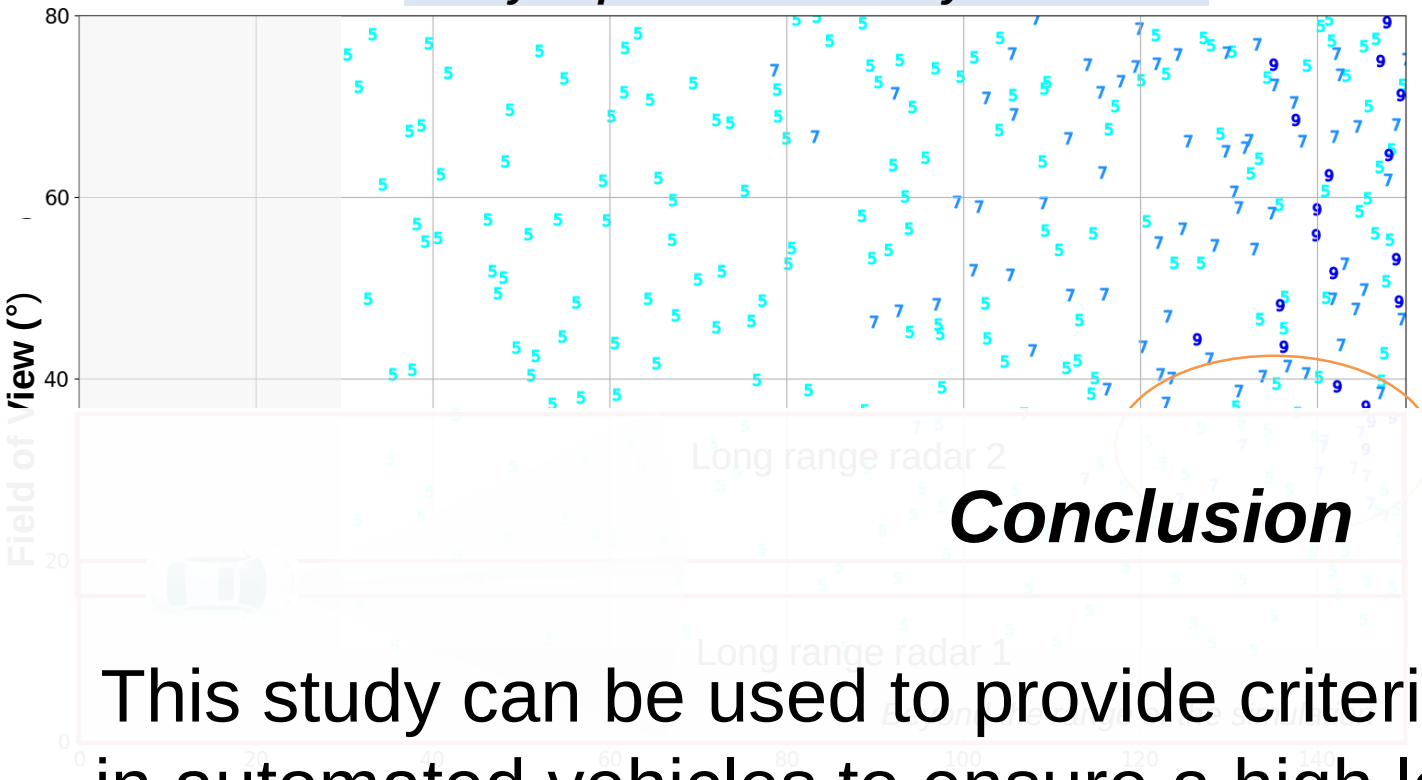
***more than one long-range radars* can be considered to obtain wider FOV**

5 **Velocity: 40 - 50 km/h** **7** **Velocity: 50 - 70 km/h** **9** **Velocity: 70 - 90 km/h**

Sensor configuration in terms of integrated safety

- Direction for supplementing sensor configuration to meet the safety requirement

Safety requirement: Fatality risk < 0.05



Conclusion

To meet the safety requirement from a vehicle with velocity *greater than 50km/h*,

more than one long-range radars can be

This study can be used to provide criteria for equipping sensors in automated vehicles to ensure a high level of integrated safety

Thank you

(jinsil.lee@dlr.de)