Assessment and Certification of SEooC Components

Outline

- SP Technical Research Institute of Sweden
- Safety contracts for Safety Elements out-of-Context (SEooC)
  - Example on assessment and certification process for SEooC by using safety contracts
  - SafetyADD tool developed by SP (SafeCer project)
- Fault injection at different abstraction levels
  - MODIFI tool (MOGENTES/BeSafe/VeTeSS projects)
  - FI-based B2B testing of SEooC components using MODIFI and GOOFI (VeTeSS)
- Safe transitions from automated to manual driving (SHADES project)

SP in figures

SP Group owners	100% RISE
Subsidiaries	10
Employees	1400
Turnover	EUR 148 million
Customers	More than 10,000

Certification

Activities


Active Safety
Concrete and Stone
Bioeconomics
Fire Research
Structural and Solid Mechanics
Certification
Electronics
Energy Technology
Glass Research
Agricultural and Environmental Engineering
Calibration and Verification
Chemistry, Materials and Surfaces
Food and Biotechnology
Machine Testing and Inspection
Measurement Technology
Process Development
Water
Wood Technology

Participation in EU projects on Dependable systems

DECOS: SP evaluated e.g. effects of communication faults (using TTTech disturbance node)

MOGENTES: SP developed e.g. a B2B fault injection testing tool chain

SARTRE: Platoons, cooperative systems, SP responsible e.g. for communication nodes

ActiveTest: Testing of active safety systems, successor to eVALUE project

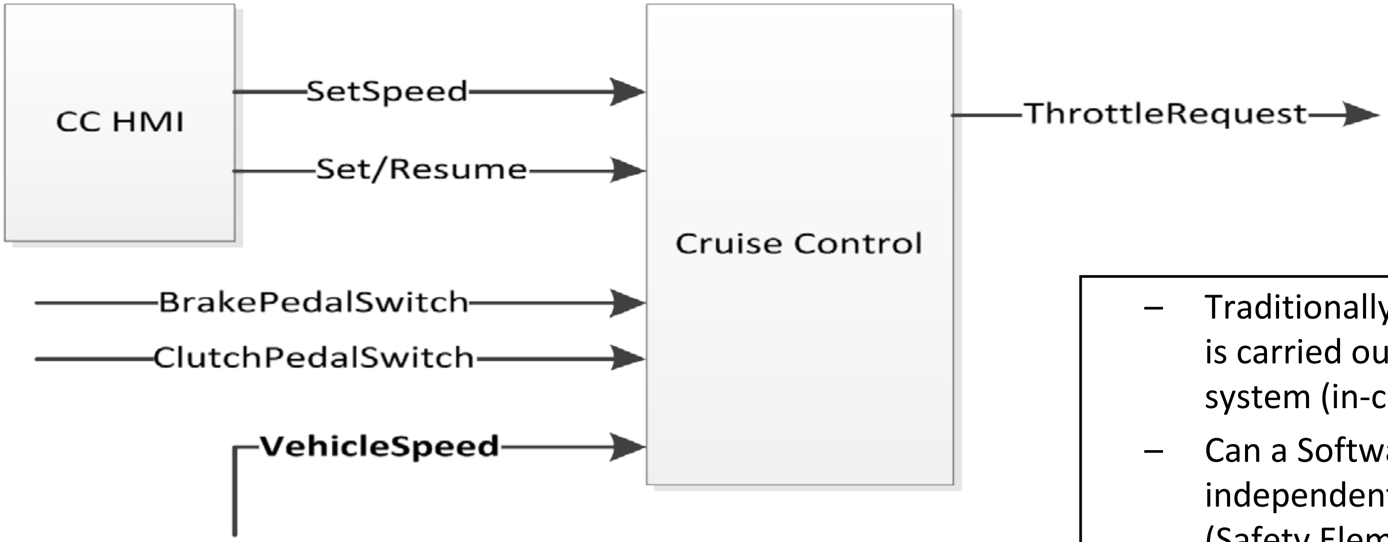
SafeCer: Safety certification, reusable SW components, safety arguing for composable systems

VeTeSS: Verification & Test Support for Safety Standards, SEooC (Safety Elements out of Context). SP has e.g. enhanced the work with FI-based B2B testing for model-based design

Karyon: Predictable and safe coordination of smart vehicles that autonomously cooperate in an uncertain environment. SP developed e.g. a quadcopter demonstrator (hw, sw, wireless FI)

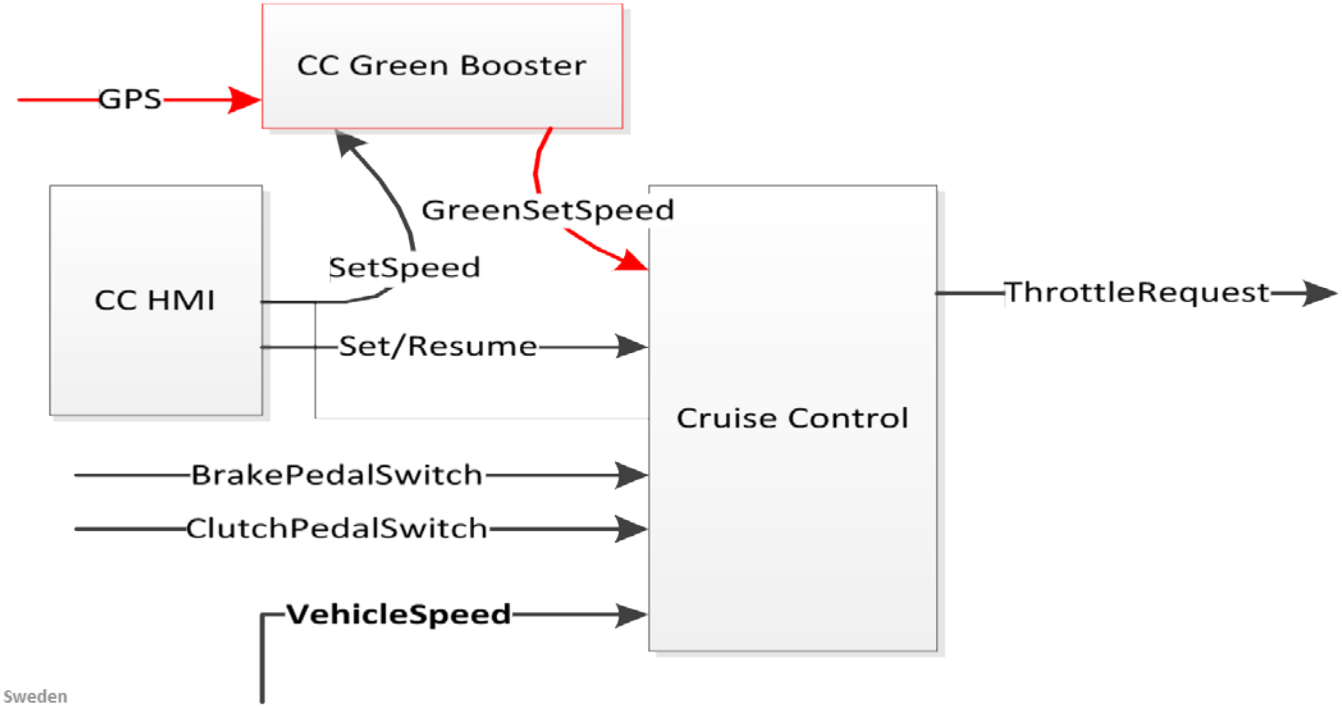
PROWESS: SP has e.g. combined Fault injection (evaluate/exercise fault handling) and Property-based testing (finding bugs) in the same experiments

Safety Contracts - Cruise Controller Example



- Traditionally, safety certification is carried out on a complete system (in-context)
- Can a Software supplier develop independent improvements (Safety Element out-of-Context)?
- How is responsibility for safety distributed then?

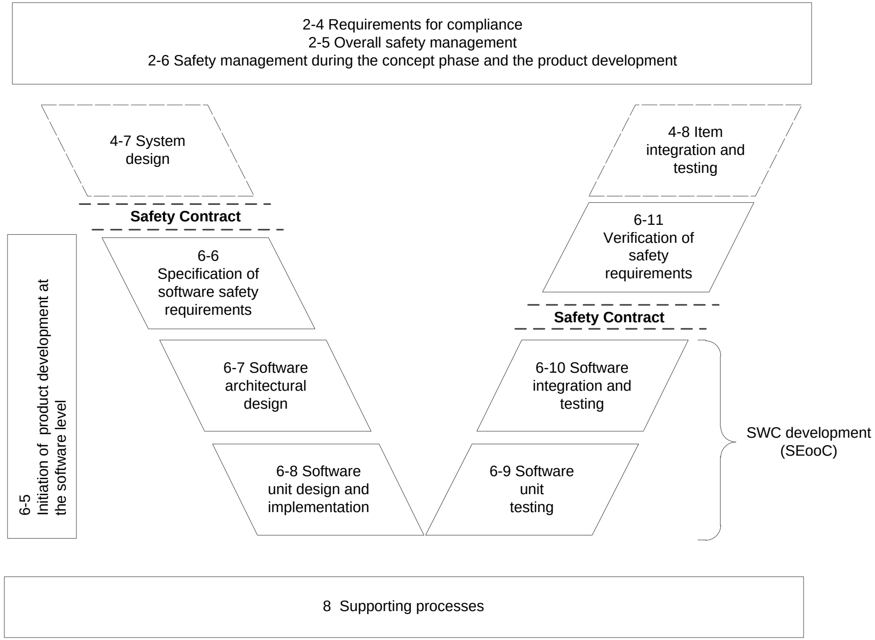
Independent innovation by SW Supplier



Safety Contract – Tailoring of ISO 26262 Safety Life Cycle

ISO 26262

Part 1: Vocabulary
Part 2: Management of functional safety
Part 3: Concept phase
Part 4: Product development at the system level
Part 5: Product development at the hardware level
Part 6: Product development at the software level
Part 7: Production and operation
Part 8: Supporting processes
Part 9: ASIL-oriented and safety-oriented analyses
Part 10: Guideline on ISO 26262



Safety Element Contract

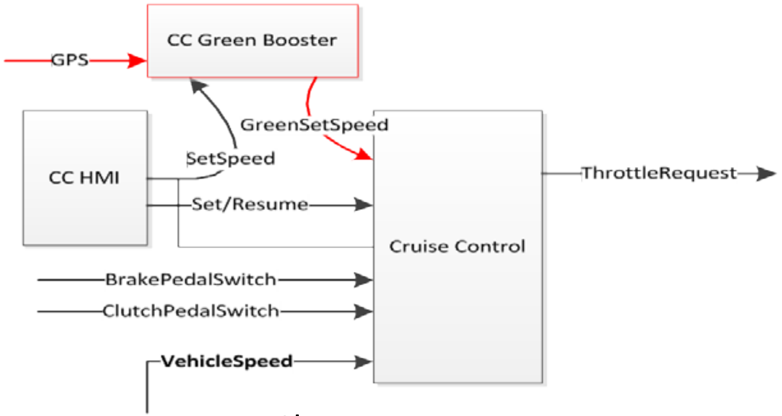
Safety Element Contract

Guarantee

- GreeSetSpeed never over 5% of driver's chosen speed more than 10s, ASIL A
- GreeSetSpeed never over 25% of driver's chosen speed more than 1s, ASIL A

Assume

- SetSpeed as specified by CC HMI with a maximum delay of 0,2s, ASIL A

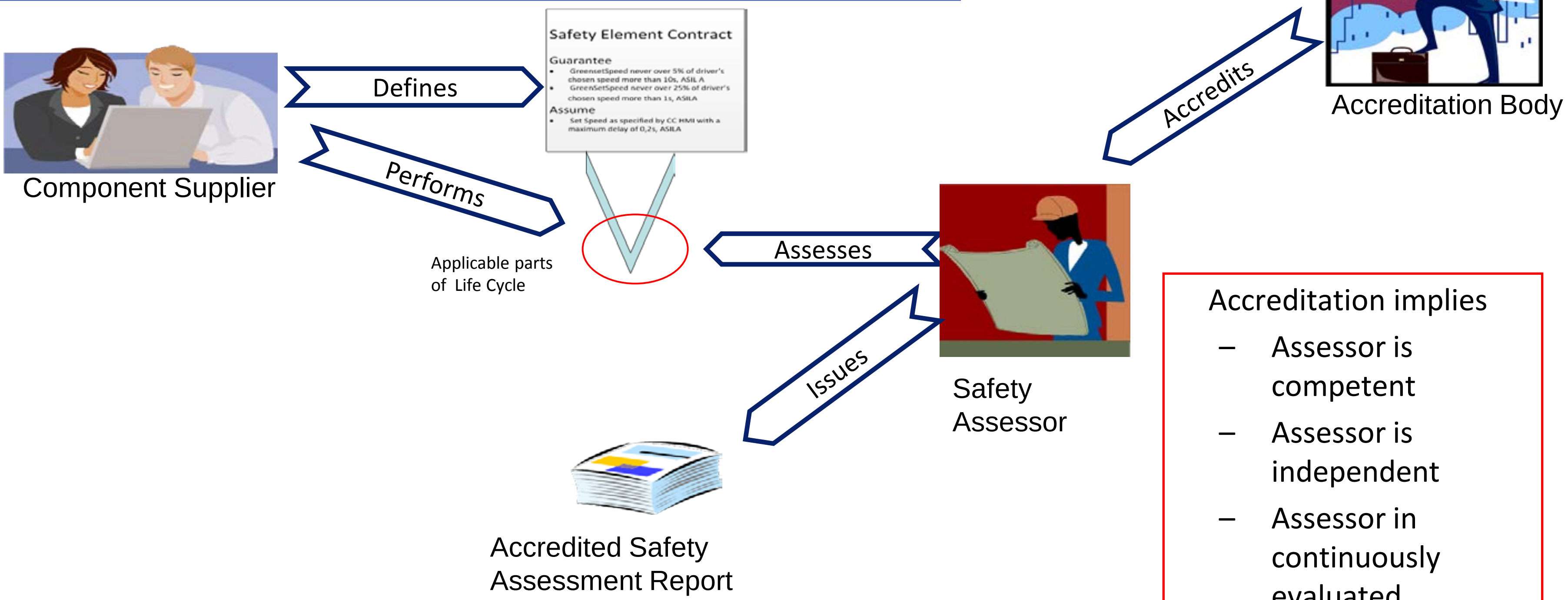


Data Sheet

references

Accredited Independent Assessor

Accreditation Body
- An authority
- Not a safety assessor



Accreditation implies
- Assessor is competent
- Assessor is independent
- Assessor in continuously evaluated

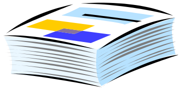
Summarizing in Certificate

Safety Assessment Report

- Contains many details
- Irrelevant for OEM
- Intellectual Properties not to share with OEM

Certificate

- Sufficient information OEM needs for Safety Case
- Not containing sensitive IP
- Suited to publish on supplier's web site



Accredited Safety Assessment Report

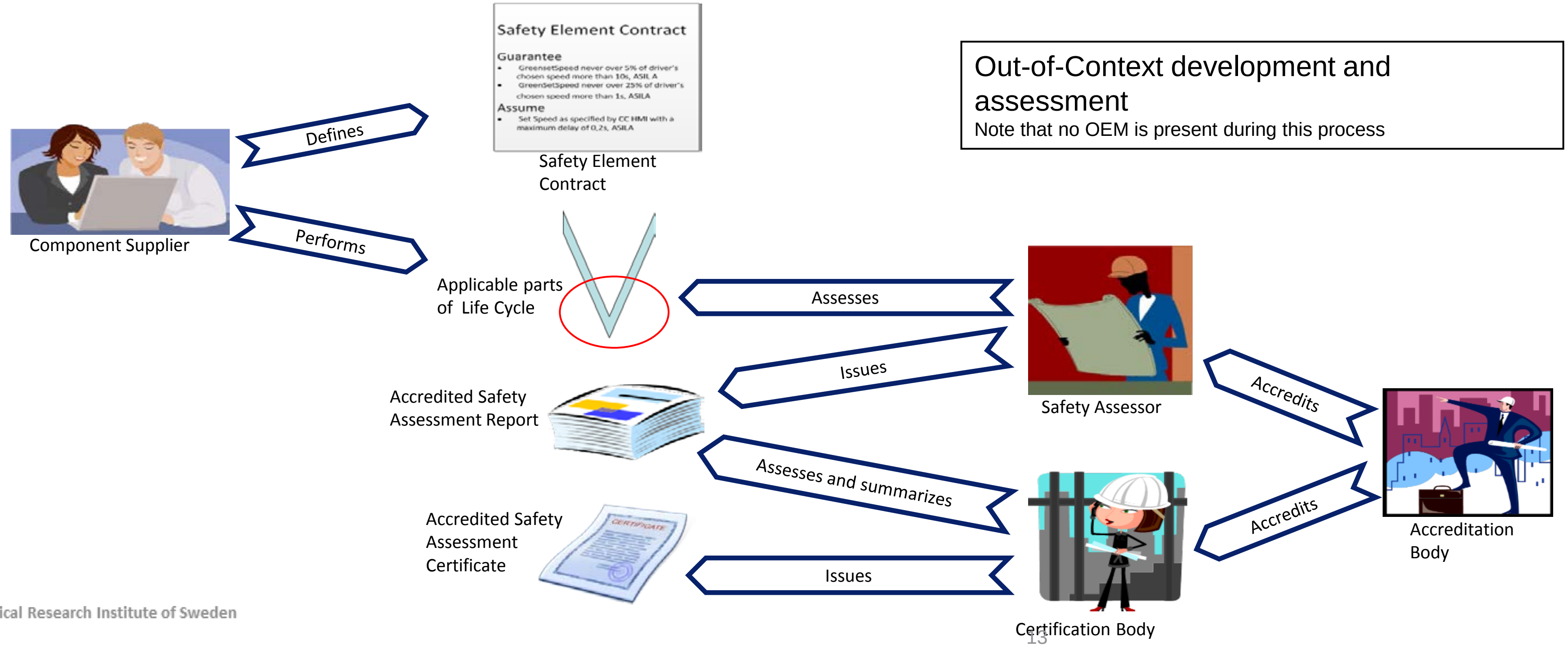
Assesses and summarizes

Safety Assessment Certificate

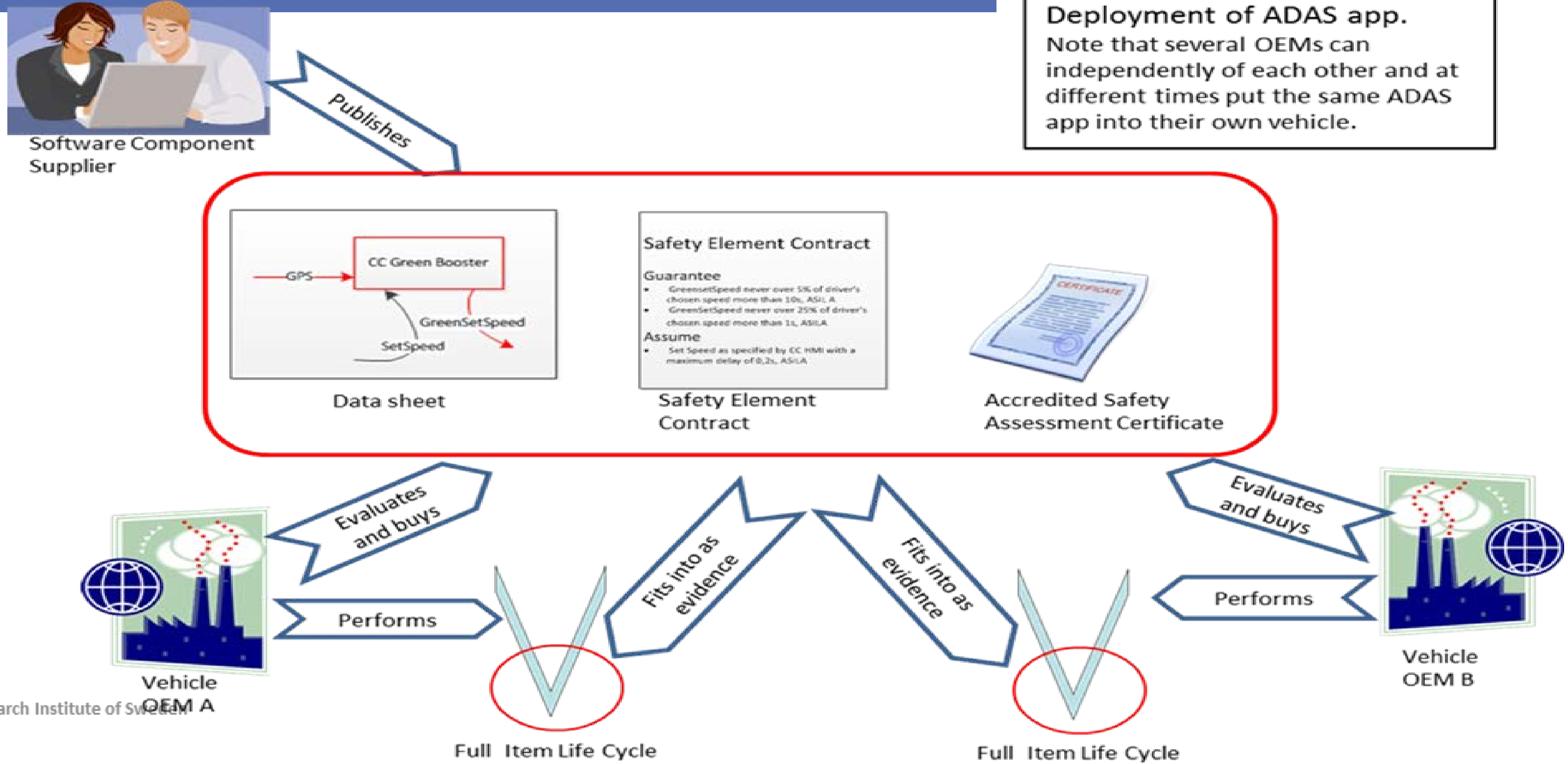
Issues

Certification Body

Out-of-Context Development and Assessment

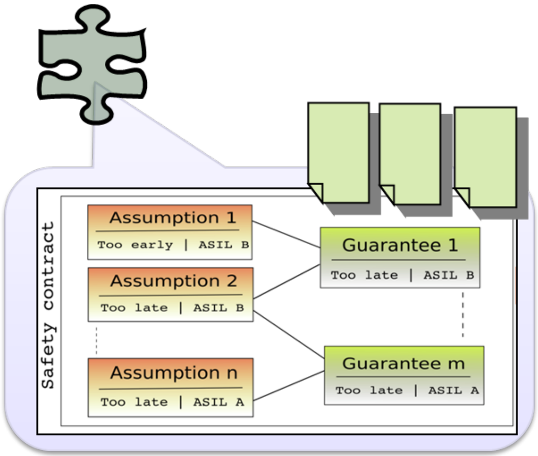


SEooC Deployed by Several OEMs

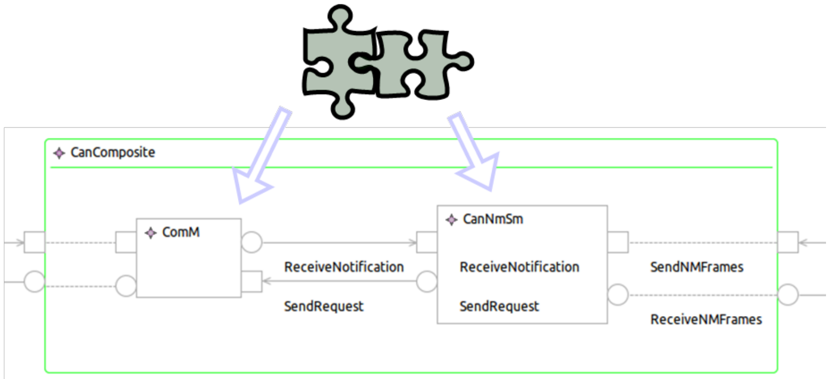


Deployment of ADAS app.
Note that several OEMs can independently of each other and at different times put the same ADAS app into their own vehicle.

Safety contract based design using SafetyADD



Safety contracts specifies a components' *guarantees* and associated *assumptions*, along with *verification evidence*.

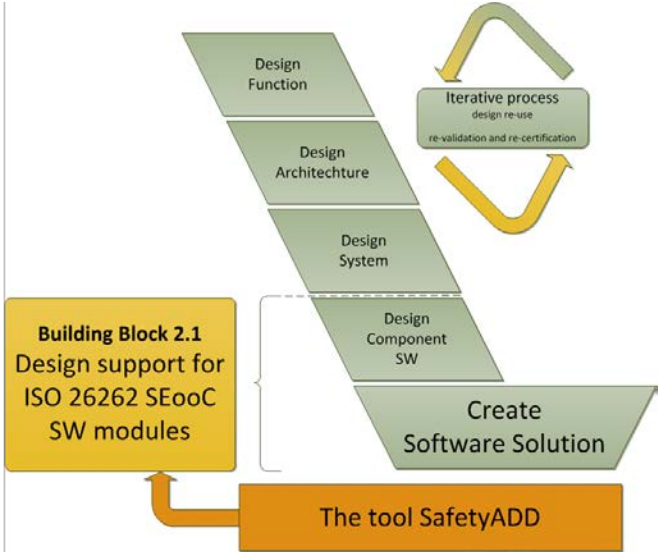


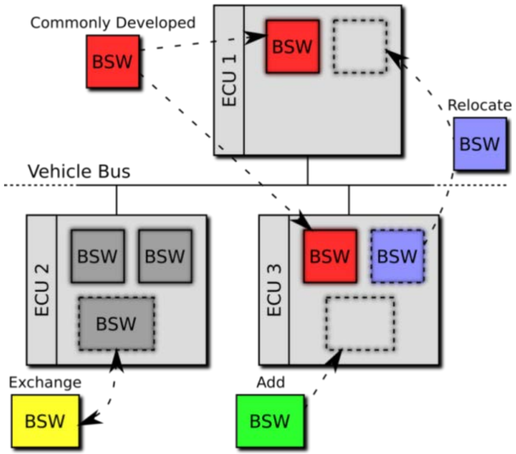
Check that guarantees and assumptions match when components are integrated.

SafetyADD tool developed in SafeCer to support these activities.

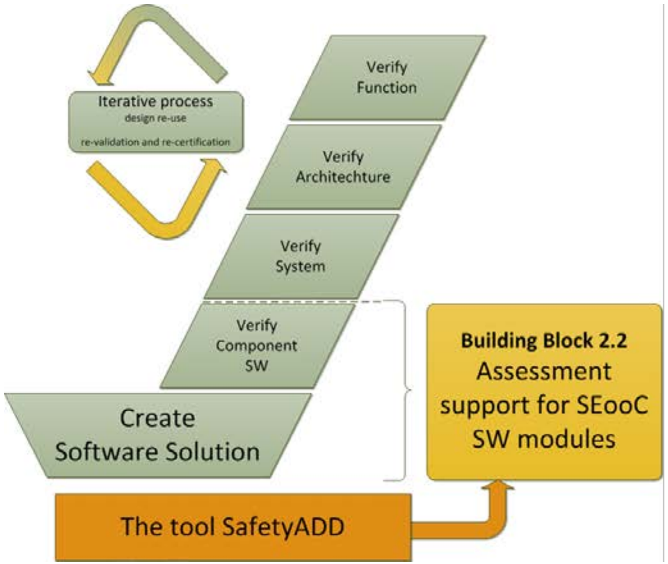
Design support

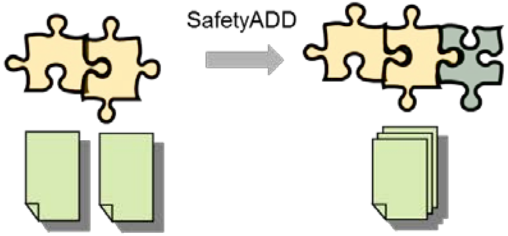
Safety contracts on an AUTOSAR BSW reduce the complexity in handling re-use and changes to design.





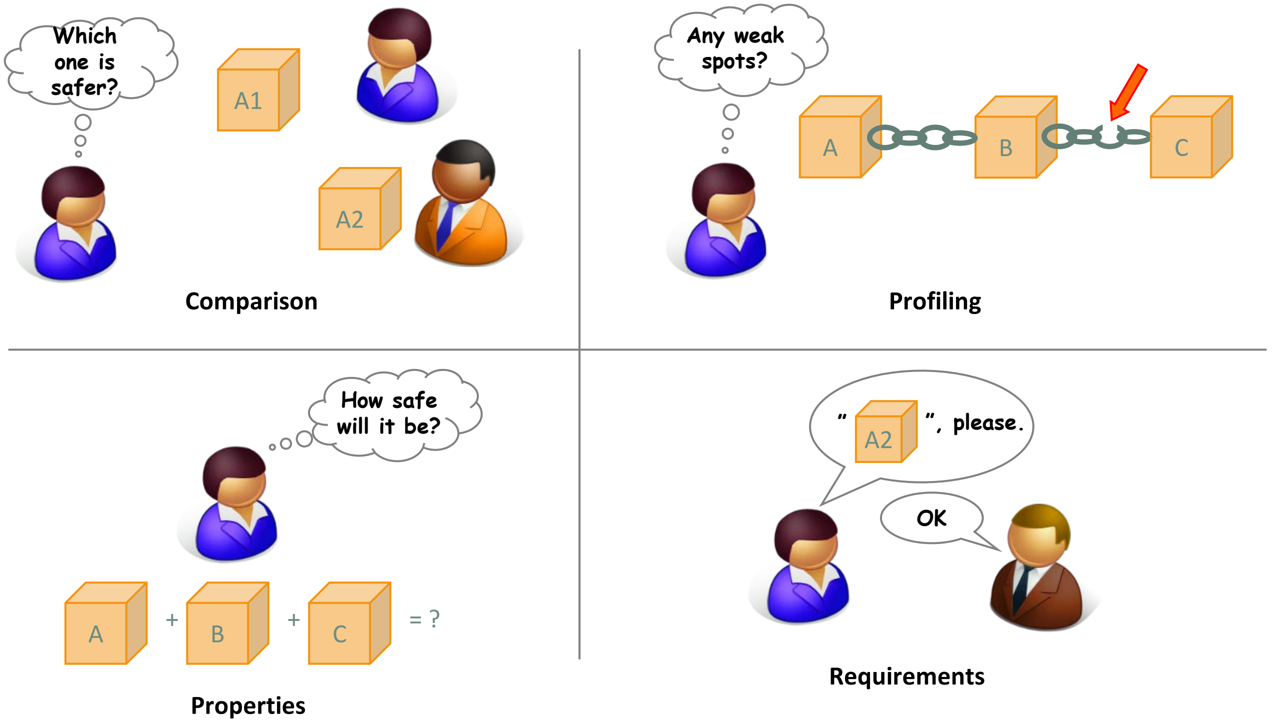
Assessment support





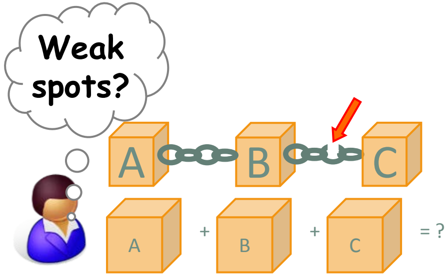
Aggregation of verification evidence and other artifacts into a bundle to be integrated into a safety case is simplified by the tool, also aid impact analysis.

BeSafe - Benchmarking of Functional Safety

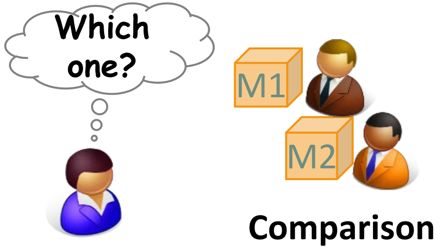


Benchmarking (fault injection) at model level

- Bugs found during design are cheaper to fix compared to bugs found during testing
- Iterative improvement of models using benchmarks
- Model-based development → Automatic code generation
  - Fault-tolerant code can be generated from models with benchmarked fault handling
- Comparison of similar designs (versions) of models
  - "Model 1 has higher error detection coverage"
  - "Model 2 has less severe failures on the output"
- Models can be used as a specification to sub contractors where fulfillment of functional safety benchmarks is a requirement



Profiling and Properties

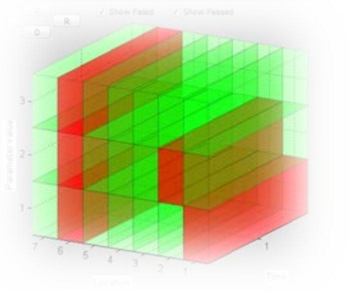


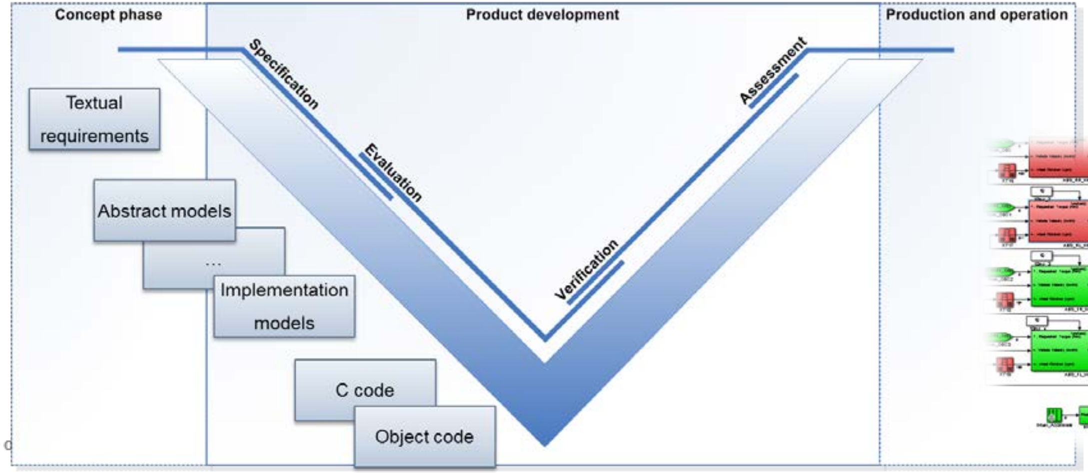
Comparison

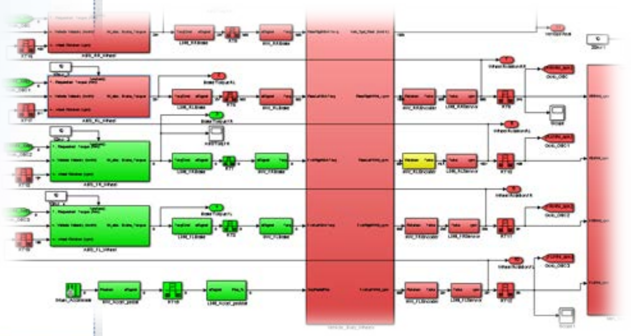
Requirements

MODIFI (MODel-Implemented Fault Injection) tool

- MODIFI is a fault injection tool for Simulink models
  - Useful for early dependability evaluation of software developed as models
  - Provides a large number of fault models, e.g., bit-flip faults and sensor faults
  - Includes support for analyzing and visualizing fault injection results

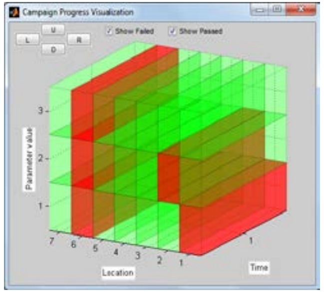


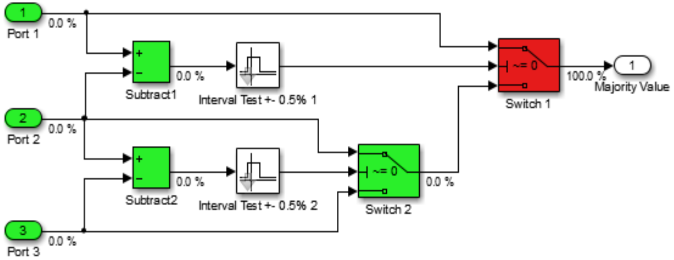


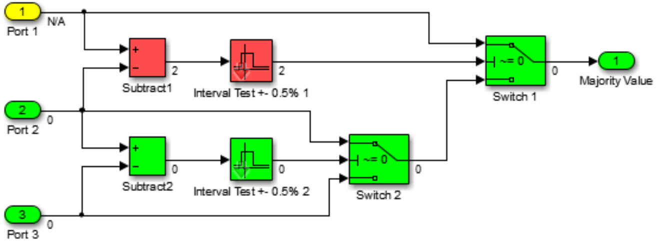


Visualization techniques

- Progress visualization for real-time status of fault injection campaigns
- Sensitivity profiling for robustness visualization (for a FI campaign)
- Error propagation analysis for understanding of the model and for evaluation of error handling mechanisms (for a single FI experiment)







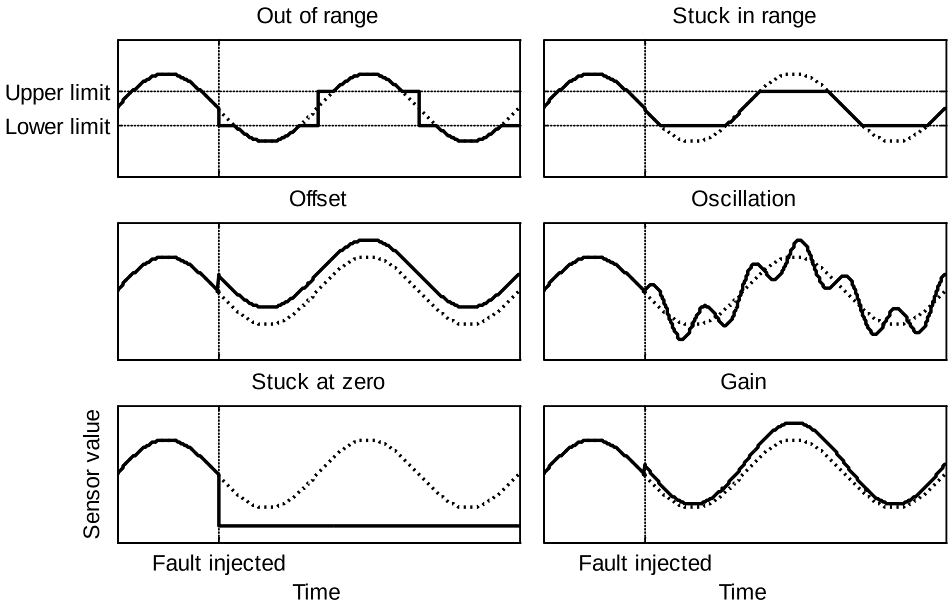
Fault models (Failure modes) – ISO 26262

- ISO 26262 Part 5 - Product development at the hardware level
  - Table D.1 - Analyzed faults or failures modes in the derivation of diagnostic coverage

- ISO 26262 fault models include (from Table D.1):
  - Sensor (including signal switches) faults
    - Stuck-in-range (Low DC = 60%)
    - Stuck-out-of-range (Low DC = 60%)
    - Offsets (Medium DC = 90%)
    - Oscillations (High DC = 99%)
  - “direct current (d.c.) fault model”
    - Stuck-at faults, stuck-open, open or high impedance outputs, short circuits
  - “soft error model”
    - Includes bit-flip faults

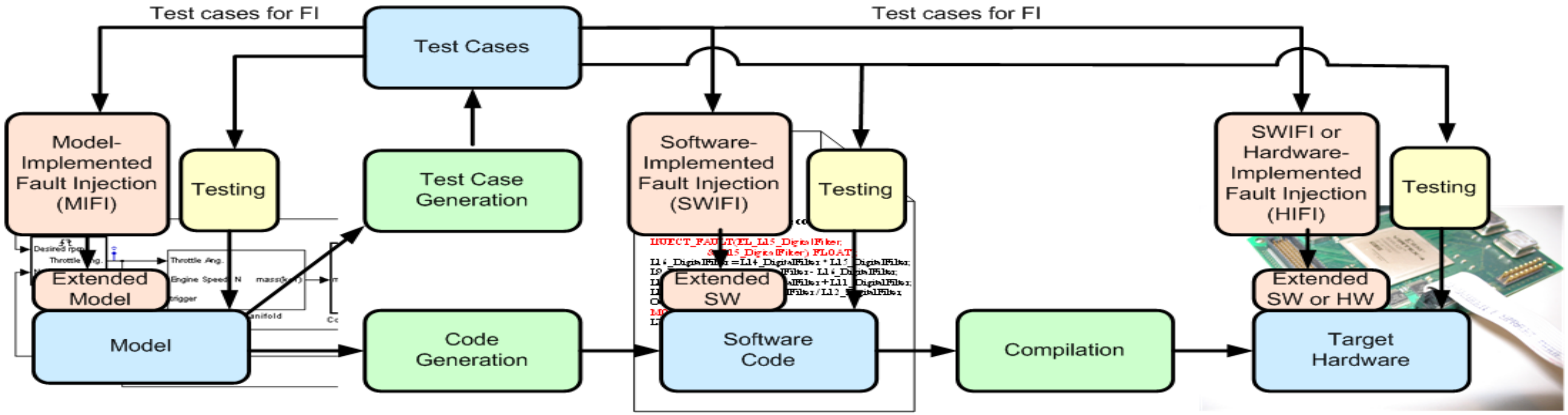
Supported fault models in MODIFI

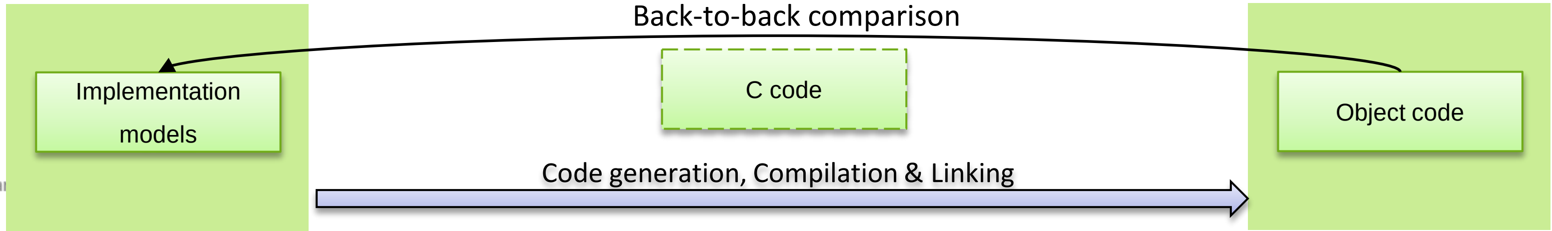
- E.g. bit-flip fault model to emulate the effects of transient faults
- Different fault models for sensors



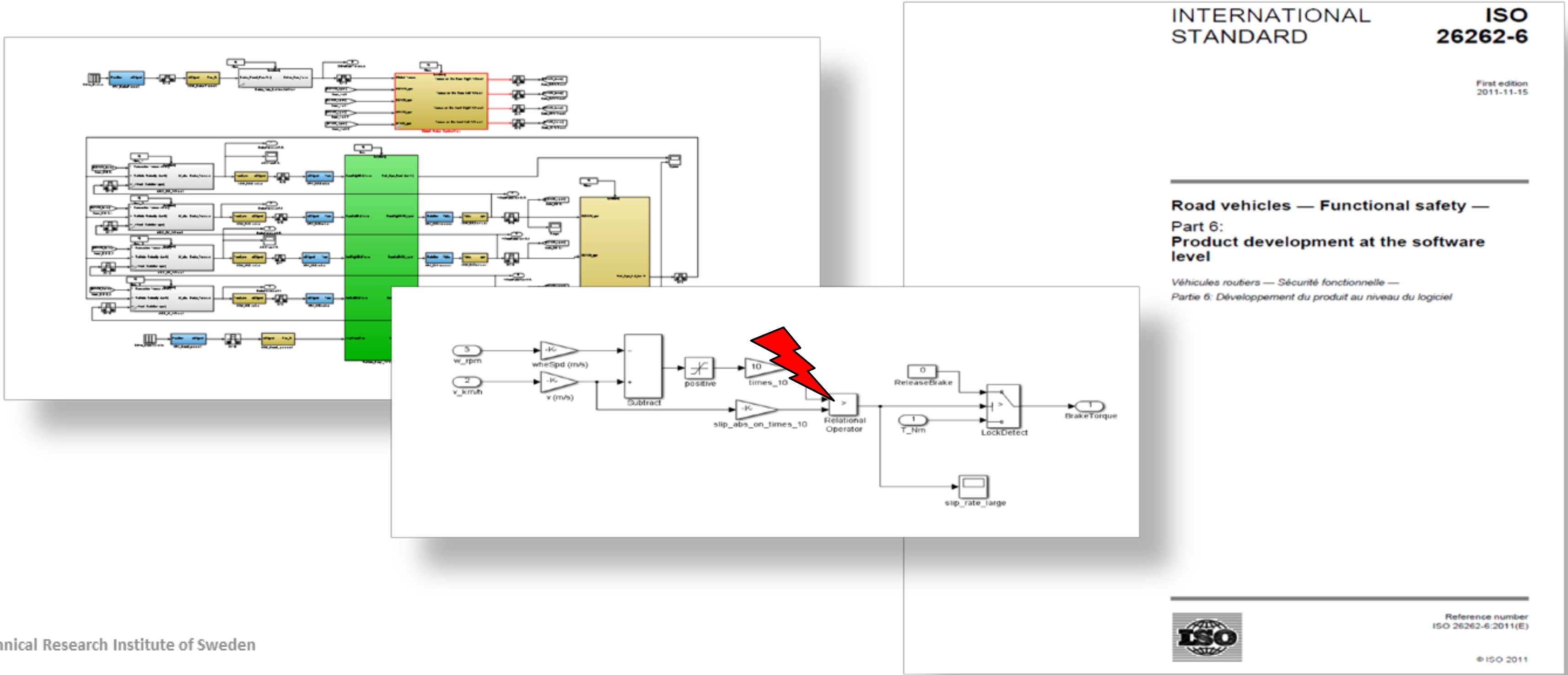
Fault Injection at Different Abstraction Levels

Model-implemented, software-implemented and hardware-implemented fault injection



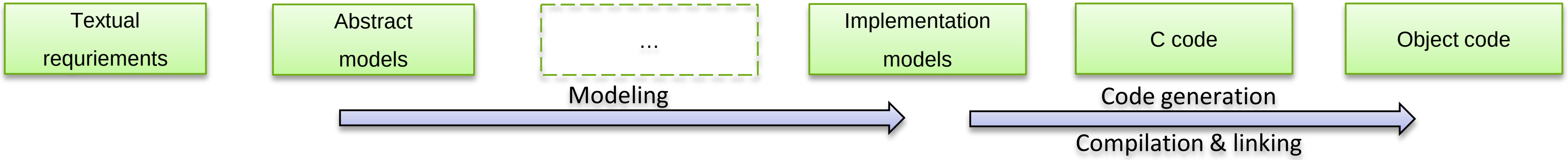


Fault injection, Simulink, Functional Safety Standard ISO 26262



Testing on models

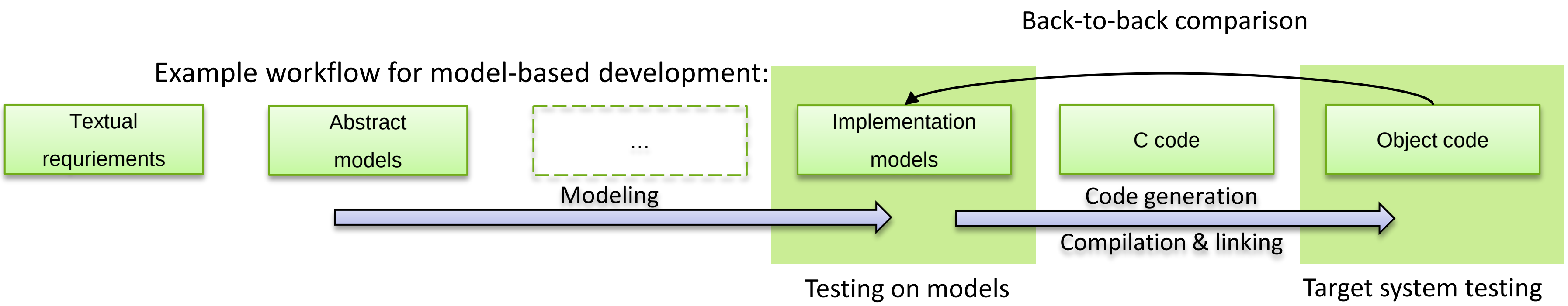
Example workflow for model-based development:



“The test environment for software unit testing shall correspond as closely as possible to the target environment. …”

ISO2626-6, 9.4.6

Testing on models (cont'd)



For model-based development:

ISO2626-6, 9.4.6 NOTE 4

- Perform software unit testing at the model level
- Use back-to-back comparison to ensure that the behaviour of the models with regard to the test objectives is equivalent to the automatically-generated code

Example workflow (to be presented at SafeComp15)

Objective: Demonstrate that software developed using Simulink models achieves robustness.
(ISO 2626-6, 9.4.3, 10.4.3)

- Fault injection is needed to test error detection and handling.

1. Select workload and faultload
2. Perform fault injection on the Simulink model using MODIFI
3. Generate code from model, compile and download to target HW
4. Use physical fault injection (GOOFI) and perform back-to-back testing with the same workload, but a subset of the faultload
5. Check that the obtained results are equivalent with respect to the test objectives

Safe transitions from automated to manual driving

- Separate slides…

- Thanks for your attention

- Questions?

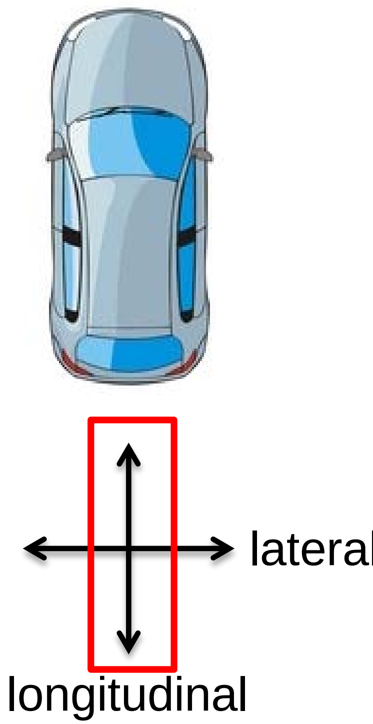
The SHADES project

SHADES - **S**ystem safety through combination of **H**MI **a**nd **De**pendable **S**ystems

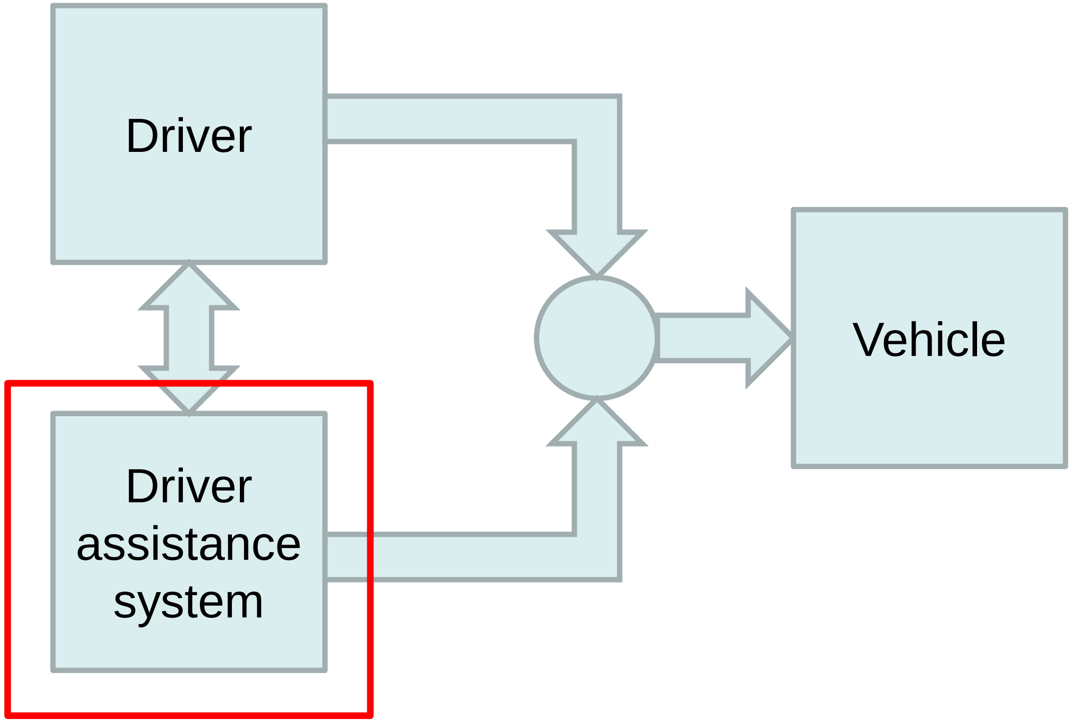
SP Technical Research Institute of Sweden

Driver assistance systems

- Information/Warning Systems
  - Forward Collision Warning
  - Lane Departure Warning
  - Blind Spot Monitoring
- Active assistance/Semi automation
  - Collision Avoidance by Braking
  - Lane Keep Assist
  - Adaptive Cruise Control
- Full/High automation
  - Lateral and longitudinal automation
  - Platooning



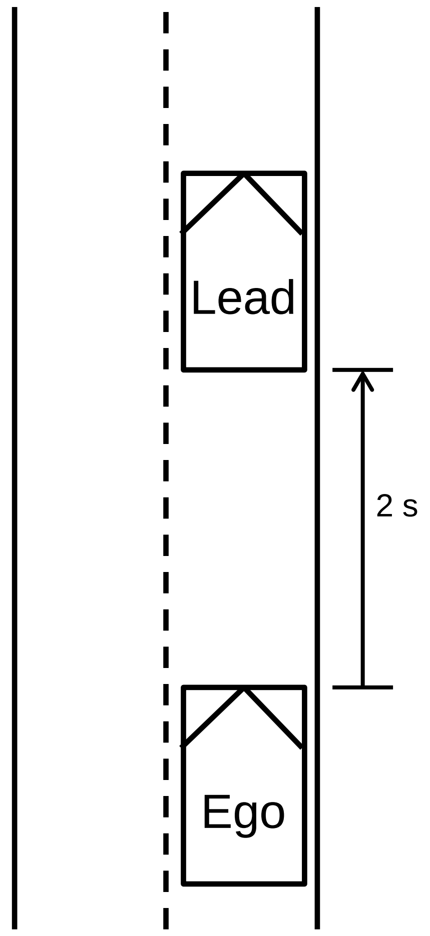
Focus in this study



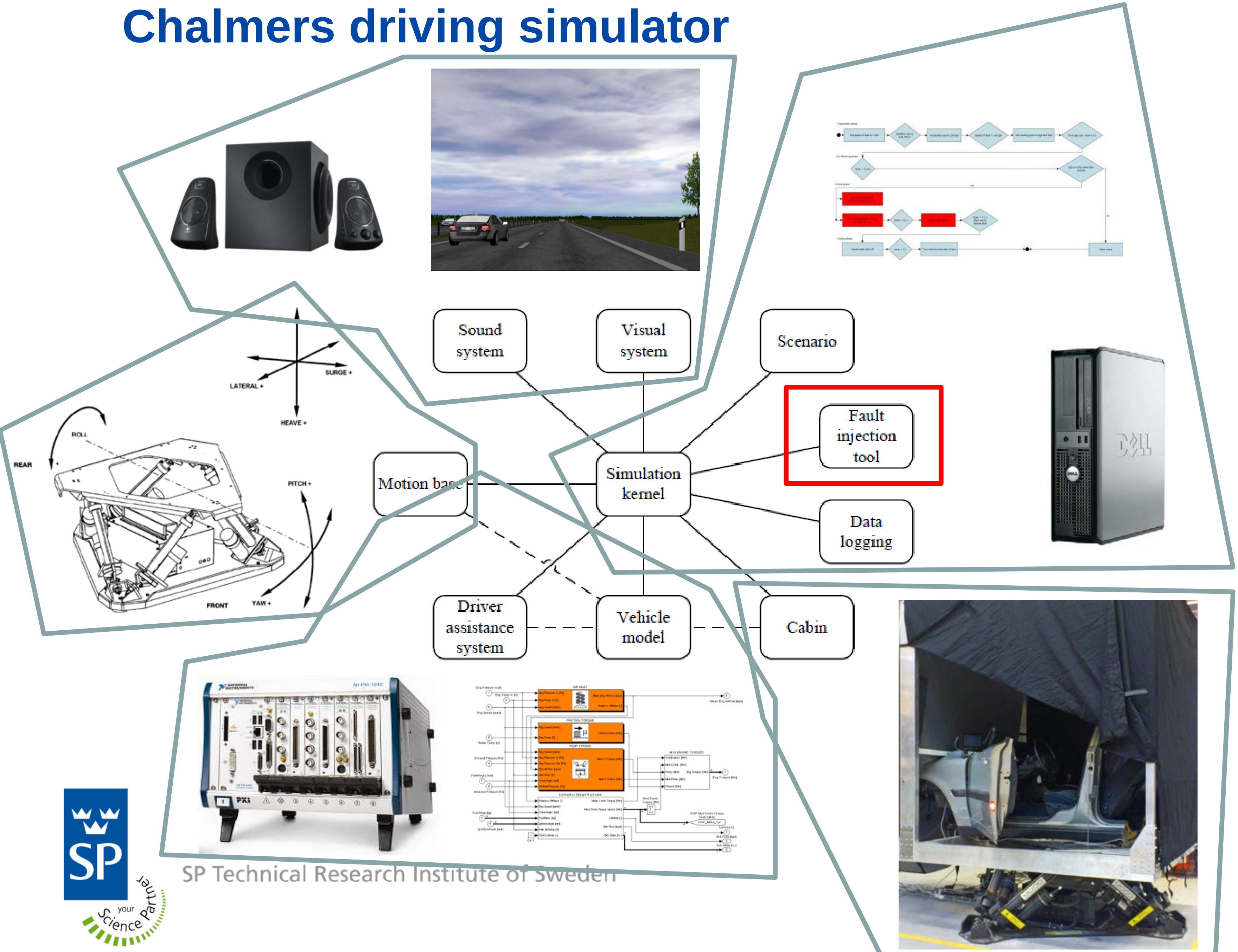
malfunctions that cause hazards

Experimental setup

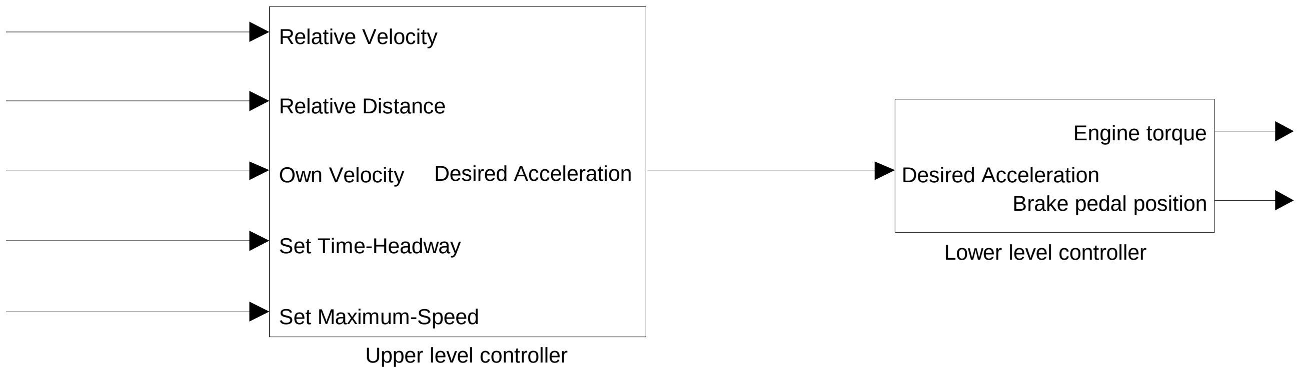
- Adaptive Cruise Control (ACC)
- Driving simulator study
- Four failure modes
  - Unwanted acceleration
  - Complete brake failure
  - Partial brake failure
  - Speed limit violation
- There was no warning indicating a failure
- All with the same initial settings
  - ACC activated
  - 105 kph (65 mph)
  - Following leader with a 2 second time-gap
  - No vehicle in left lane (free to overtake)



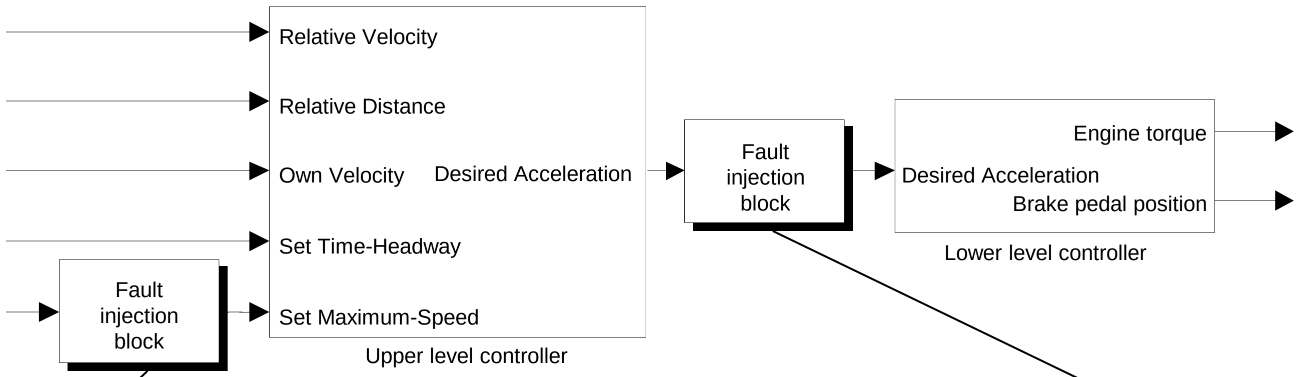
Chalmers driving simulator



Driving simulator experiment – Fault injection support



Driving simulator experiment – Adaptive cruise control



Speed failure

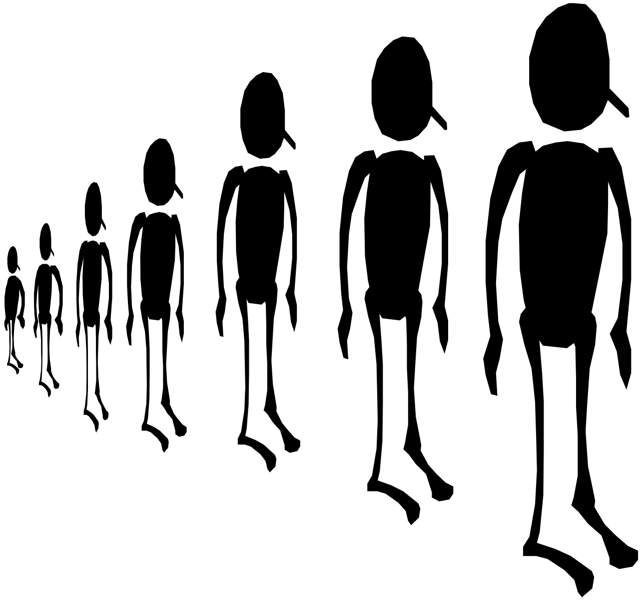
Unwanted acceleration

Complete brake failure

Partial brake failure

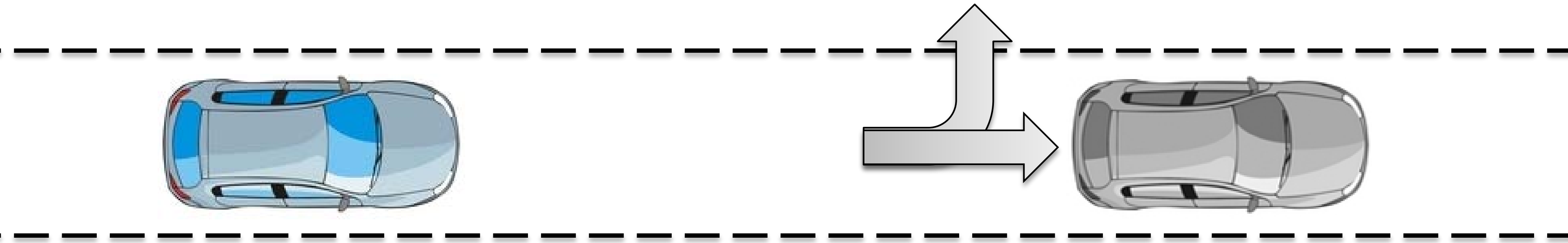
Participants

- 48 participants
  - 33 men and 15 women
  - between 25 and 59 years of age
  - annual driving distance more than 5000 km
  - no experienced ACC users



Scenario A: Unwanted acceleration

Car in front drives at 105 kph (65 mph), ACC in ego car accelerates unintentionally towards vehicle ahead (fails to keep the set distance and speed)



Fails to follow leader with a 2 second time gap

Braking or steering required to avoid collision

Scenario B&C: Complete and partial brake failure

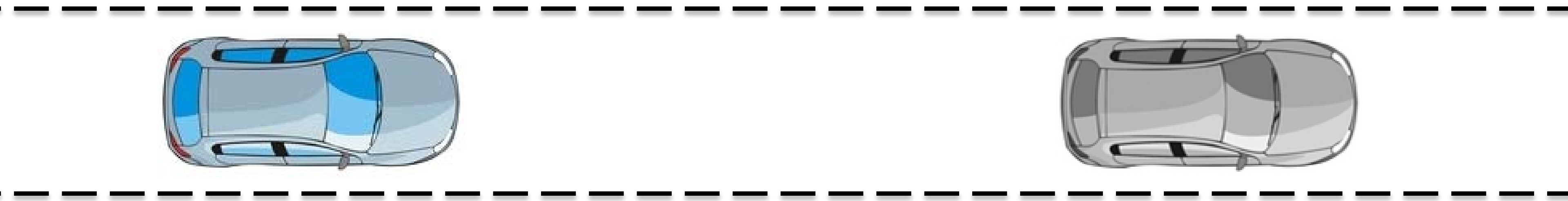
B: Car in front brakes, ACC in ego car does not brake

C: Car in front brakes, ACC in ego car brakes less than necessary to avoid a collision

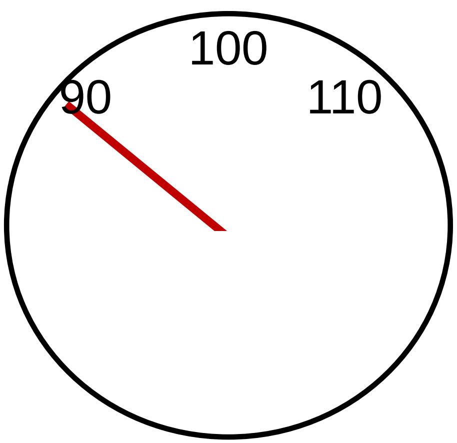
Braking or steering required to avoid collision

Scenario D: Speed limit violation

Car in front accelerates above speed limit, ACC in ego car also accelerates keeping set distance (2s) but fails to keep set speed limit (110 kph)



Following leader with a
2 second time-gap



Braking required
to avoid speeding

Sweden

Design

	Order of scenarios		
Subjects	**1**	**2**	**3**
n = 4	Practice	**A**	**B**
n = 4	Practice	**B**	**A**
n = 4	Practice	**A**	**C**
n = 4	Practice	**C**	**A**
n = 4	Practice	**A**	**D**
n = 4	Practice	**D**	**A**
n = 4	Practice	**B**	**C**
n = 4	Practice	**C**	**B**
n = 4	Practice	**B**	**D**
n = 4	Practice	**D**	**B**
n = 4	Practice	**C**	**D**
n = 4	Practice	**D**	**C**

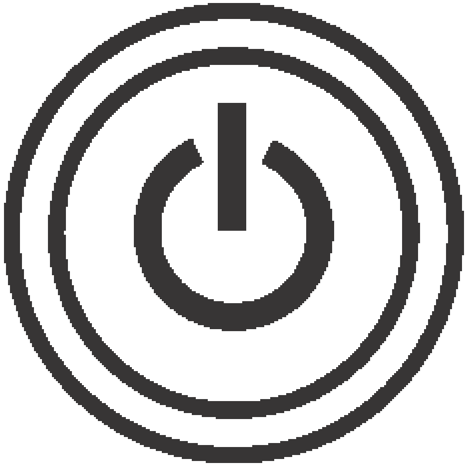
* A=B=C=D=Experimental scenario including experimental situation and preceding baseline

** N = 48

*** n = 24 for each experimental scenario

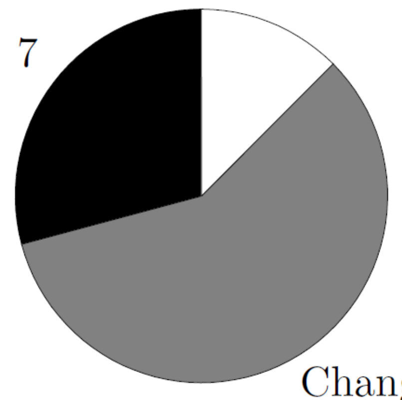
RESULTS

The drivers available strategies when system fails



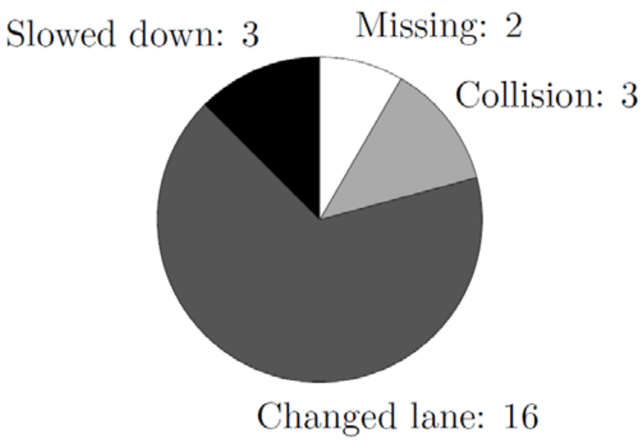
Scenario A: Ego car accelerates unintentionally

- No collisions
- Majority used steering
- One third slowed down
  - Six braked
  - One turned off the ACC using the button
- Three drivers got the vehicle unstable which automatically aborted the experiment

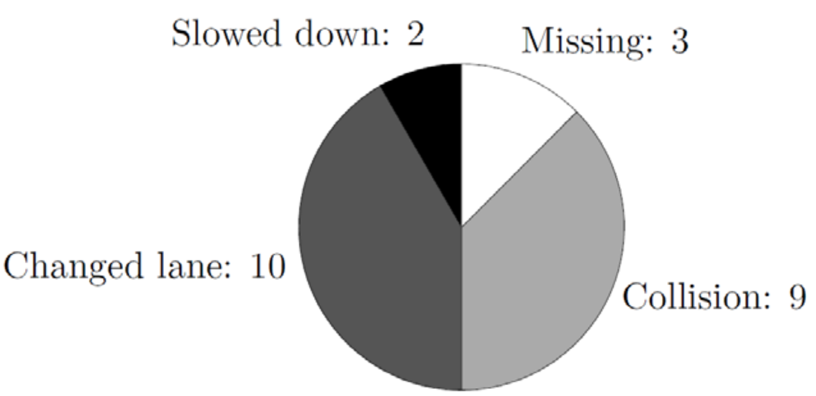


Scenario B&C: Brake failures

- Both brake failures caused collisions
- Partial brake failure caused more collisions than complete failure
  - But with lower impact speed (36 kph vs. 82 kph)!
- Changing lane most common for drivers with successful outcome



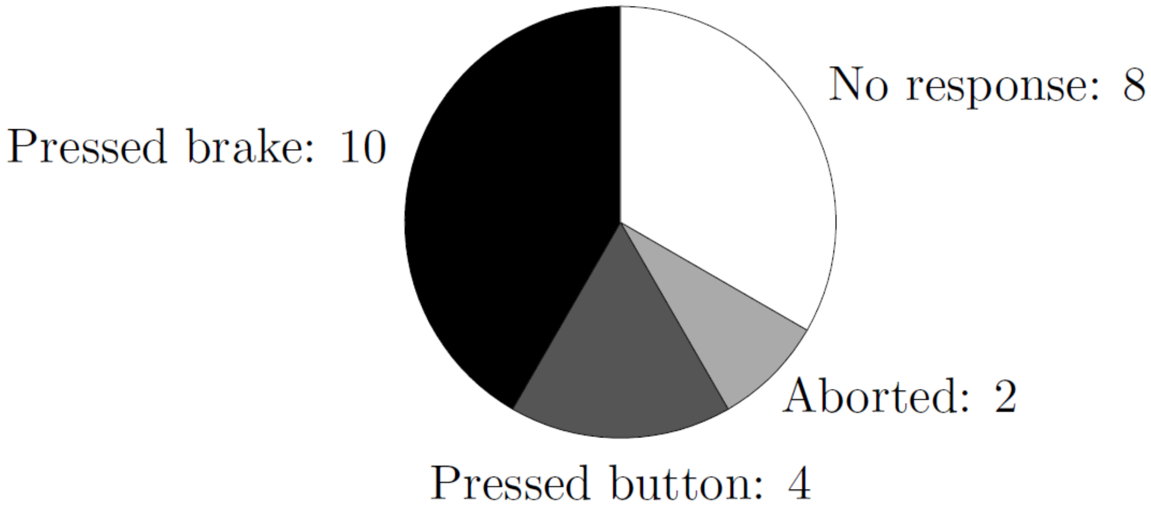
Complete brake failure



Partial brake failure

Scenario D: Ego car accelerates keeping the set distance but fails to keep the set speed limit

- Eight drivers did nothing within 30 seconds of speeds above 110 kph
- Braking more common than pressing the ACC on/off button



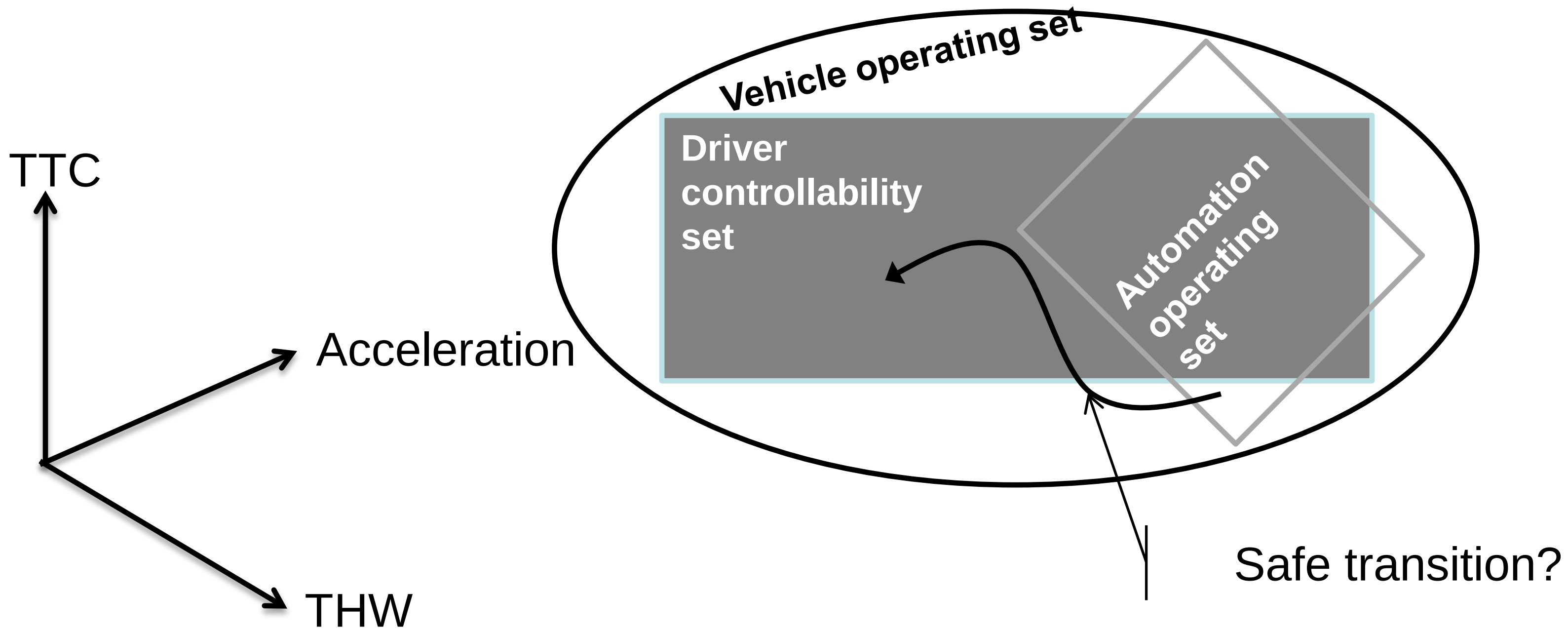
Conclusions

- More drivers changed lane than braked to acceleration and brake failures
  - But note that drivers were always free to change lane
- Collisions only occurred in scenarios with brake failures
- More collisions for partial brake failure than for complete brake failure
  - However, impact speed was less for partial brake failure
- Comparing brake failures:
  - Higher controllability for complete brake failure (fewer collisions)
  - Lower severity for partial brake failure (lower impact speed)

Risk = Exposure x Controllability x Severity

Human Interactive Autonomous Driving – *Challenges*

- Safe transitions from automated to manual driving?
  - Disable automated control may not be safe!
  - How should the driver be included in the loop when system fails?
    - Driver cannot take over in all situations ➔ Back-up needed?
  - What can the system do before including the driver?



Human Interactive Autonomous Driving – *Research Perspectives*

- Cooperation needed between different research areas
  - Main goal of the SHADES project
  - E.g. Human behavior science, Control theory and Dependable systems

- Drivers can behave differently depending on level of automation
  - We have carried out a driving simulator study (with brake failures) comparing longitudinal control (ACC) with longitudinal and lateral control (Traffic Jam Assist, TJA)
  - Preliminary simulator results show that going from ACC to TJA leads to worse performance when longitudinal automation fails