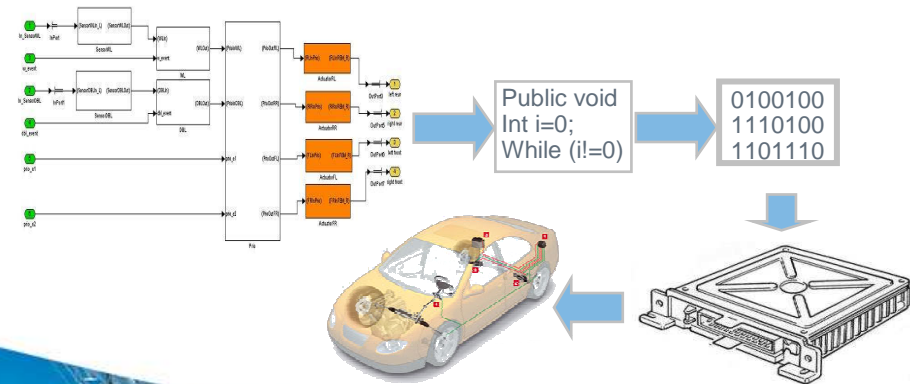


# Evaluating costs and benefits of model-based development of embedded software systems in the car industry – Results of a qualitative Case Study

Case Study results, Paris June 15<sup>th</sup> 2010  
ECMFA 2010 Workshop: C2M:EEMDD  
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## Agenda

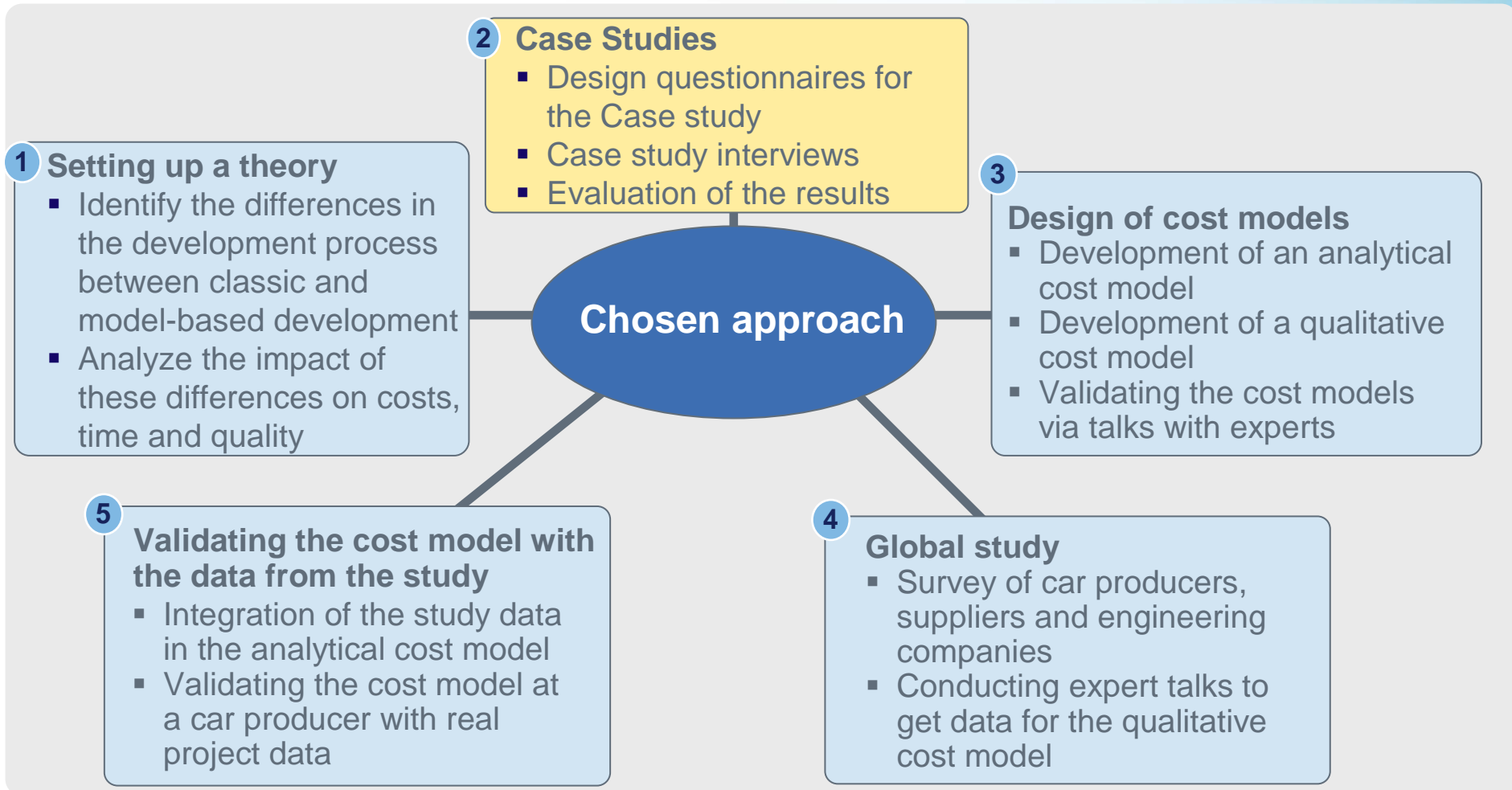
**1 – Introduction**

**2 – Main results of the case study**

**3 – Identification of Best Practices in model-based design**

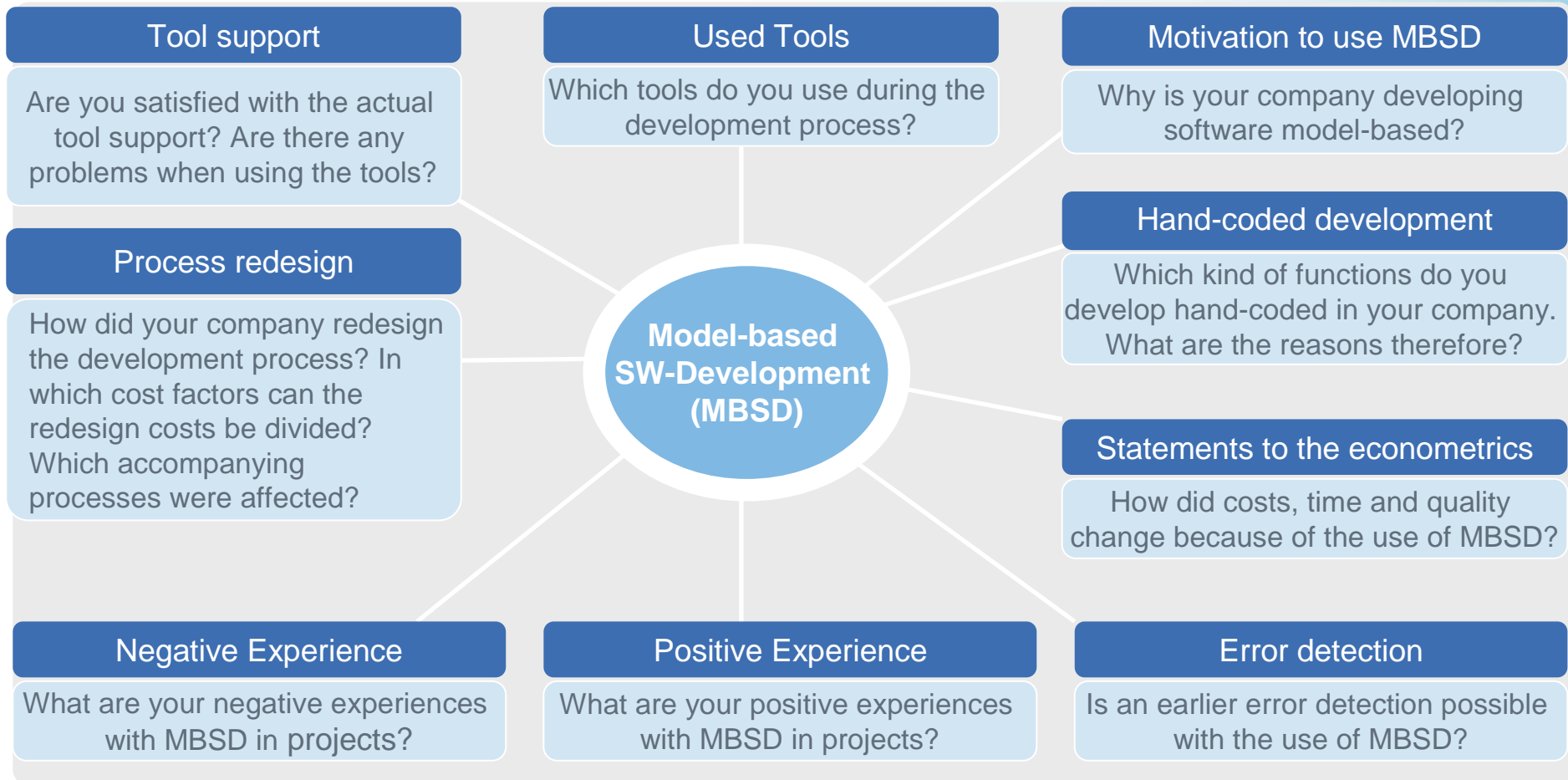
## Classification of the case study in the overall picture

The conducted case study is part of an intensive investigation of the economics of model-based software development (MBSD), which is conducted as a PhD thesis at the university of technology in Munich



## Covered topics in the case study

The case study covers versatile aspects about model-based development. Therefore experts from the domain power train, chassis, energy management and comfort functions were interviewed regarding the following questions



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## Process redesign (1/2)

Main cost drivers in the process redesign are not just tool costs

### Costs for the process redesign

Main cost factors	Influence on the Costs	Influence on the Time
Licence and support costs for tools	High	None
Definition and introduction of a new development process	High	Medium
Changes in the organisational structure	High	Medium
Training of the employees	Medium	High
Costs for living the process	Medium	High
Costs for the improvement of the development process	High	High
Design of already hand-coded developed projects	High	High

## Process redesign (2/2)

Before model-based development is used for a series project, several pilot studies are being conducted

### Used procedure for the process redesign

Evaluation of tools

At the beginning all available tools on the market are being analysed and balanced. Therefore tool evaluations are being conducted

Drafting of a new development process

With the results of the tool evaluation the development of the new development process is being started. Depending on the used tool chain the process has to be adapted to the companies needs

Conduction of pilot studies

The developed process is validated via pilot studies. Pilot studies help the engineers to get used to the new development process without any pressure of a series project and to be able to judge the benefit of the new approach

Adoption of the defined process

Usually process improvement potential is already identified in the first pilot study. The improvement potential is included in the iterative design of the development process

Conduction of further pilot studies

The case studies are iteratively continued until the process is mature for a series development

First series project

The first series project shows, whether the defined process is suited for the series development. If the first series project is conducted successfully the new development process is being spread in the whole company

## Motivation to use MBSD

Different reasons convince companies to use model-based design

### Motivation to use MBSD

#### Company internal motivations

- Cost savings in the development
- The possibility to simulate in particular with Rapid Control Prototyping (RCP) allows the development of very innovative functions
- Companies are afraid to miss a next generation technology

#### Advantages in the development

- Higher automation in the development process
- Possibility to detect errors earlier
- Easier communication with colleagues
- Light effort for reusing function models in different car lines

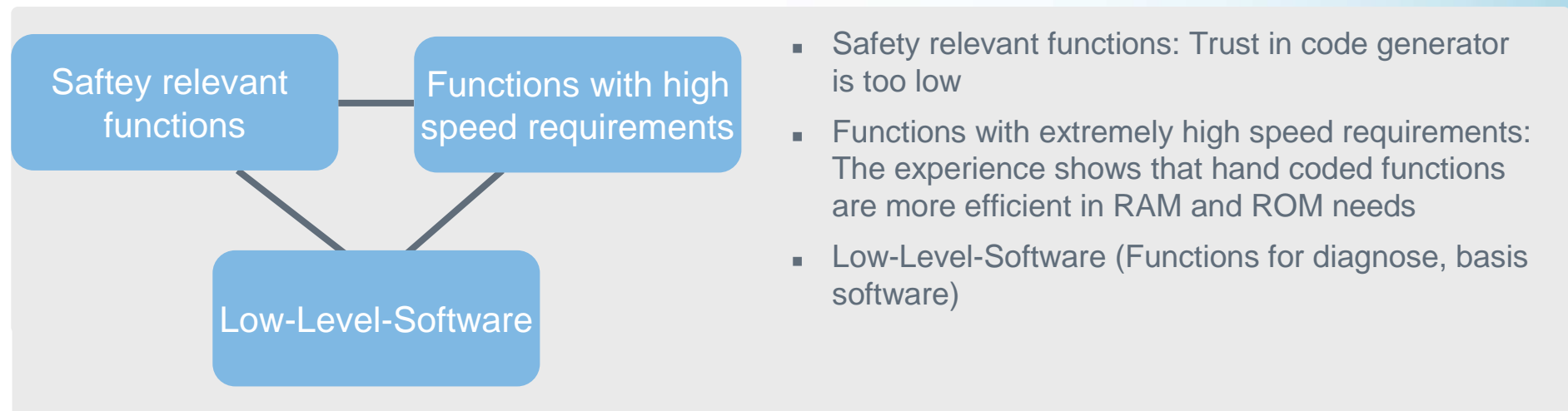
#### Competitive pressure between the suppliers

- Customer (OEM) demands that suppliers use model-based development
- Supplier want to impress the customer (OEM) that they already use the newest development technology

## Hand coded development

Some functions are still being developed hand coded. Not only technical aspects, but mainly company internal reasons are responsible for that

### Hand-coded developed functions



- Safety relevant functions: Trust in code generator is too low
- Functions with extremely high speed requirements: The experience shows that hand coded functions are more efficient in RAM and ROM needs
- Low-Level-Software (Functions for diagnose, basis software)

### Company intern reasons for hand coded development

- Model-based development process is not established in all departments → Costs for the process redesign are too high (especially the licence costs for the tools)
- On the supplier side the necessity to develop model-based is sometimes not seen. The reason therefore is, that suppliers already use reuse concepts in hand-coded projects. This ensures that they can reuse their hand-coded developed functions

# Negative experiences with MBSD

The negative experiences can be divided into four aspects

## Negative experiences with MBSD

### Tools

- Dependency on tool vendors: Tool restricted interfaces
- Maturity of tools
- No seamless tools over the whole development process available

### Simulation

- Detailed knowledge necessary: Sometimes the Know-How is not available in the companies. Following simulations are not conducted intensive enough
- Simulations are time consuming especially if the function models are huge → Simulations are disregarded at high time pressure

### Development of unstructured code

- Function models are sometimes models which have gained in functionality over the years. The generated code out of these function models is often unstructured and inefficient → Application of modelling rules and reuse concepts is important

### Reusability

- Even model-based developed functions can not be reusable

## Positive experience with MBSD

The positive experiences can be divided into six aspects

### Positive experiences with MBSD

#### Easier communication

- The graphical description of function models allows an easier communication
- Screenshots of function models can be used in presentations

#### Easier development of complex functions

- With the use of RCP engineers can develop high innovative functions via try and error on a real car
- The RCP-Model often serves as an executable specification

#### Simulation

- RCP allows to develop certain functions
- Combination of RCP and Model in the Loop (MiL) allows an earlier error detection

#### Overview over the whole system

- The graphical description allows to get an overview over the whole system. It is easy to see which functions interact among each other

#### Reusability

- With the use of a reuse concept a function model can be reused in different car lines without much additional effort

#### Possibility to generate code out of function models

- All case study participants use the automatic code generation out of the function model

## Used tools

Tools for model-based development are intensively used in the software design and the implementation

### Used tools in the development process

System requirements	Word, Doors
System architecture	Powerpoint, Visio, Excel
Software requirements	Word, Doors, Matlab/Simulink/Stateflow, Ascet
Software architecture	Powerpoint, Visio, Excel, Matlab/Simulink/Stateflow, Ascet
Software design	Matlab/Simulink/Stateflow, Ascet
Implementation	TargetLink, RealTime Workshop
Test	TPT, MTest, Polyspace, own developed tools

- Tool support is seen as a big added value
- The engineers need a lot of experience to exploit the full potential of the tool support (for example simulations)
- Companies moan about the dependency on the tool vendors, because the tools don't offer open interfaces

## Error detection in the development process

The more intensive tests on models are conducted, the less errors are found in the following development phases

### Changes in the error detection

Beginning of the error detection

73% start the error detection in the requirements analysis with RCP, 27% begin in the SW-Design

Use of RCP

73% use RCP and even 63% of them use it intensively

Use of MiL

100% use MiL-Tests and even 81% of them use it intensively

### Effect of earlier error detection on the number of discovered errors

- Considerable fewer errors in the implementation and the whole test process after the implementation phase
- Reasons: RCP, MiL-Tests, model reviews and the automatic generation of code
- Impact of MBSD on the maintenance:
  - Fewer errors in the series → Fewer number of updates necessary
  - 63 % of the case study participants even report a higher product quality

## Statements about the econometrics

Case study participants report about positive impacts on the econometrics

### Statements about changes in the econometrics because of MBSD

Costs



Earlier error detection because of the use of simulations, high automation degree and easier communication. The highest cost saving potential is seen in the reuse of function models over different car lines

Time



Earlier error detection because of the use of simulations, high automation degree and easier communication. The highest cost saving potential is seen in the reuse of function models over different car lines

Product quality



Functions have a higher maturity level → Impact on the maintenance  
Participants report improvements of the quality criteria reliability, usability, maintainability and portability

**Interesting cognition:** The domain has no impact on cost, time and quality changes. This has even been confirmed by a case study participant, who has made this experience in several projects in different domains

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## From the case study interviews Best Practices can be derived

Only when you develop model-based in the “right“ way, you will be able to achieve cost savings

### Best Practice Approaches

- A **reuse concept** is also vital when developing model-based
- **Defined change overs** in the development process are more important in the praxis than to erase the seamlessness of the development process, if you have already invested a large effort in erasing the seamlessness in your development process (usually more than 5 years usage)
- Using the **potential of simulations** over the whole development process. Particularly when developing innovative functions an intensive use of RCP and MiL is recommended
- **Training of the employees** about best practices in software engineering concepts like e.g. modularisation. These concepts are very important to develop reusable and efficient code out of the function models. This knowledge can decide whether a project is conducted successfully or fails
- **Size of the function model**: It is advisable to use more small function models than one large function model
- **Selection of the appropriate tool chain** is a central aspect during the process redesign. The dependency on tool vendors is very high and consequently a change in the tool chain is comparable to a complete process redesign

## Summary

The strengths and the potential of MBSD are prized by our case study participants

### Strengths of MBSD

- Easier Communication
- Higher automation degree
- Reusability over different car lines
- Possibility to simulate models leads to an earlier error detection
- High complex functions can be developed easier
- Costs savings and improvements in quality

### Weaknesses of MBSD

- Challenges with tools
- High investments are needed for introducing and optimizing the development process
- Dependency on tool vendors
- It is a key factor to know, how to develop model-based the “right“ way. Otherwise there is a high error potential in developing model-based

### Potential of MBSD

- **Vision:** Model-based development from requirements till test with the aim to achieve synergy effects, because of more intensive model-based design
- **Problem:** Appropriate tools not available
- **Current challenges:** Expanding the model-based development on the architecture design and model-based testing

### Risks of MBSD

- **Huge Know - How necessary** to get the full potential out of MBSD. Without this Know-How MBSD can be counterproductive
- **Investments in the long run** are necessary → For small companies maybe to expensive
- **Dependency on tool vendors**

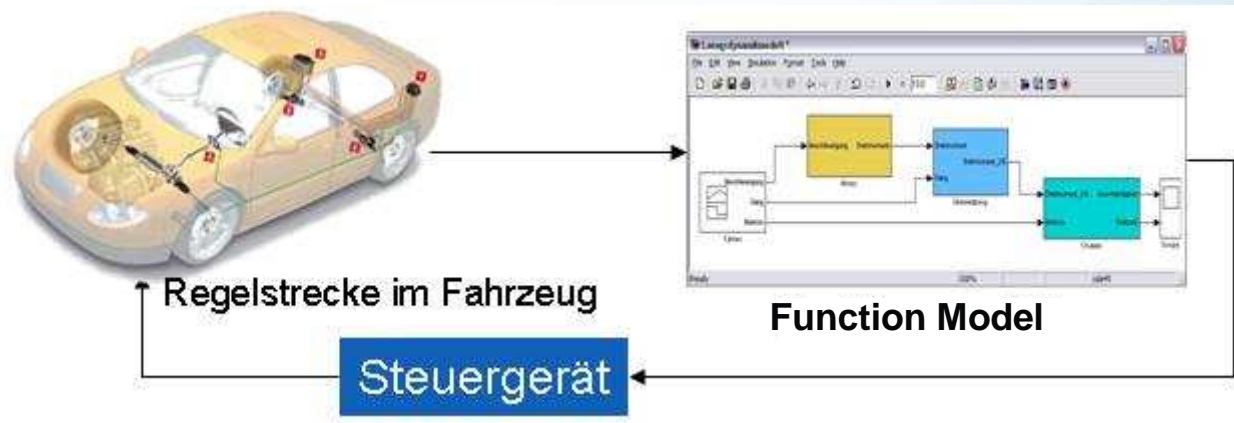
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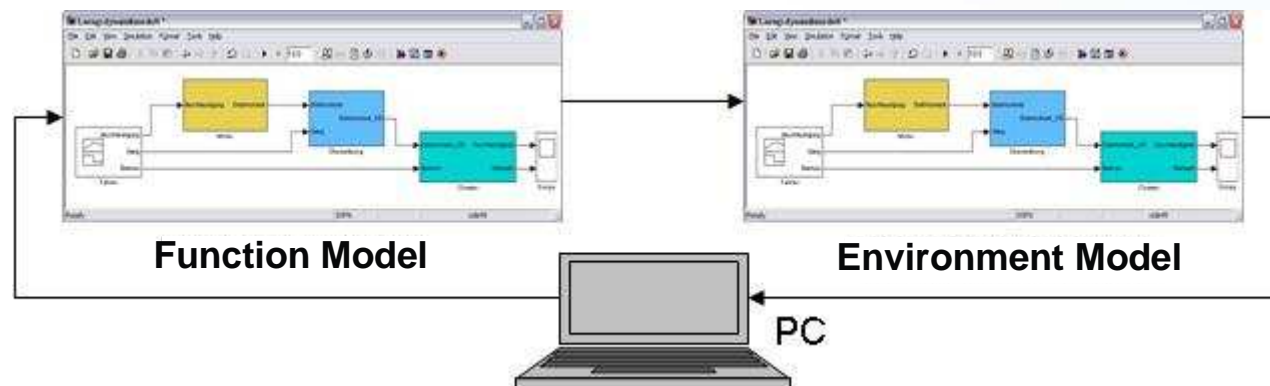
# Backup slides

RCP



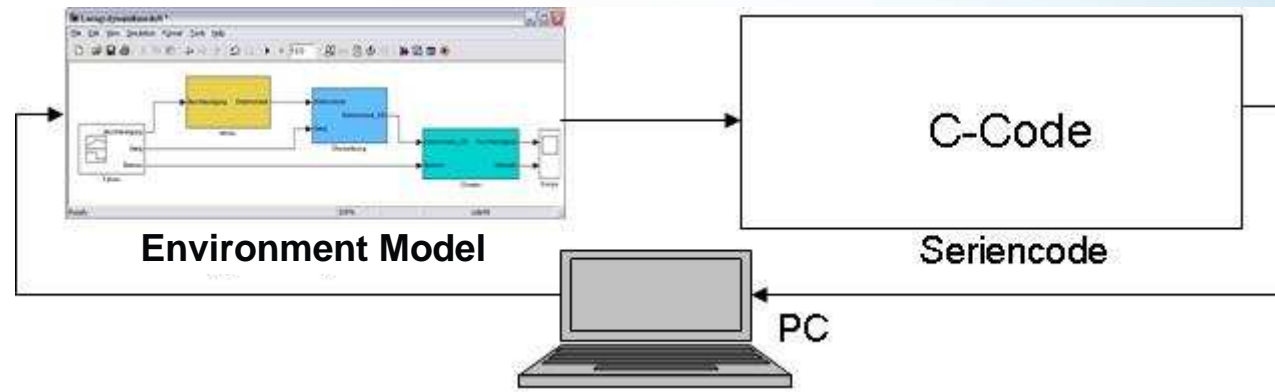
- Based on Floatingpoints
- Can be conducted on a real car or on a test bench

MiL



# Backup slides

SiL



PiL

