# Evaluation of architecture variants for hard real-time systems

Timing as part of system architecture

- **Hard real time** requirements

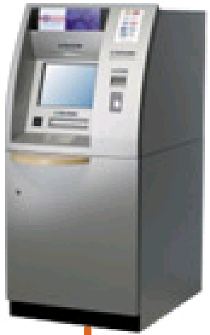
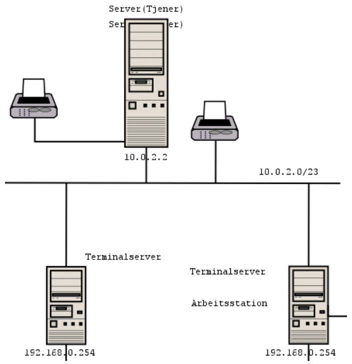
The system response time to a certain event **always** has to be **within a certain limit**



- **Soft real time** requirements

The system response time to a certain event should usually be within a certain limit.

It is not problematic if this limit is violated occasionally.

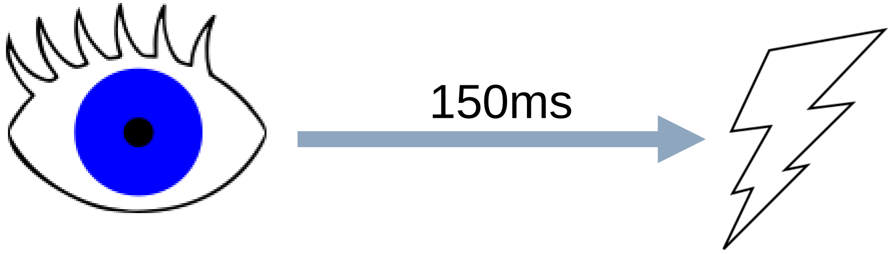

**A timing fault in a real-time system occurs when a task or interrupt misses its deadline**

# Where do temporal requirements come from?

- Physics of the system (braking distance, …)
- Resulting form system architecture (redundancies, partitioning, selection of technologies, …)
- Resulting from hardware architecture (selection of technologies, …)
- Resulting from software architecture (number of tasks, …)
- Resulting form mechanical architecture (geometry, …)

# Front AirBag System (FABSY):

The vehicle drives along the road with increased speed. Suddenly a pedestrian steps onto the road. A collision is inevitable. The FABSY-Unit detects the pedestrian, realizes that a collision is inevitable and activates the airbag, which preserves the pedestrian from severe damage.



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# How to meet timing requirements

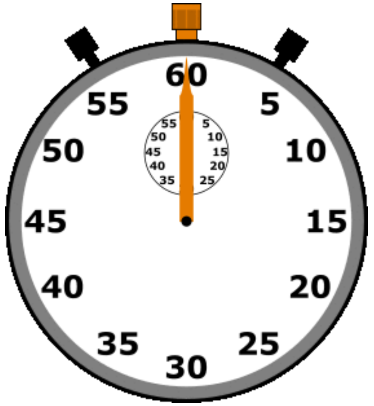
**Strategies**

- Scheduling (preemptive, non-preemptive)

- OS (priority based, preemptive)

- Watchdog based-mechanisms (e.g. Control flow analysis)

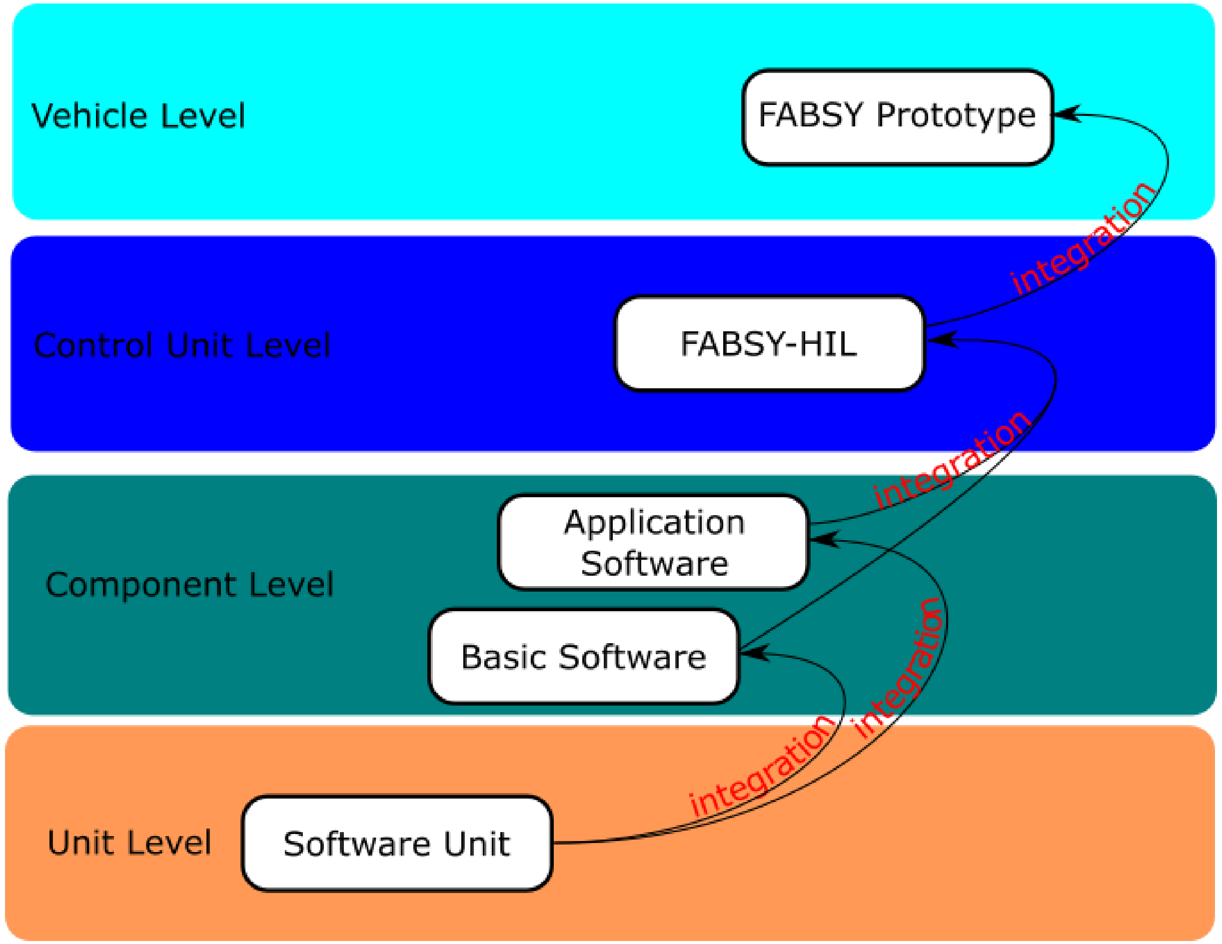
- Scheduling Bus-Protocol level




# How to meet timing requirements

**<u>Bottom-up approach:</u>**

- Software units are assembled to construct software components
- Components realize tasks (i.e., work units) in applications
- Tasks are scheduled (i.e., planned)



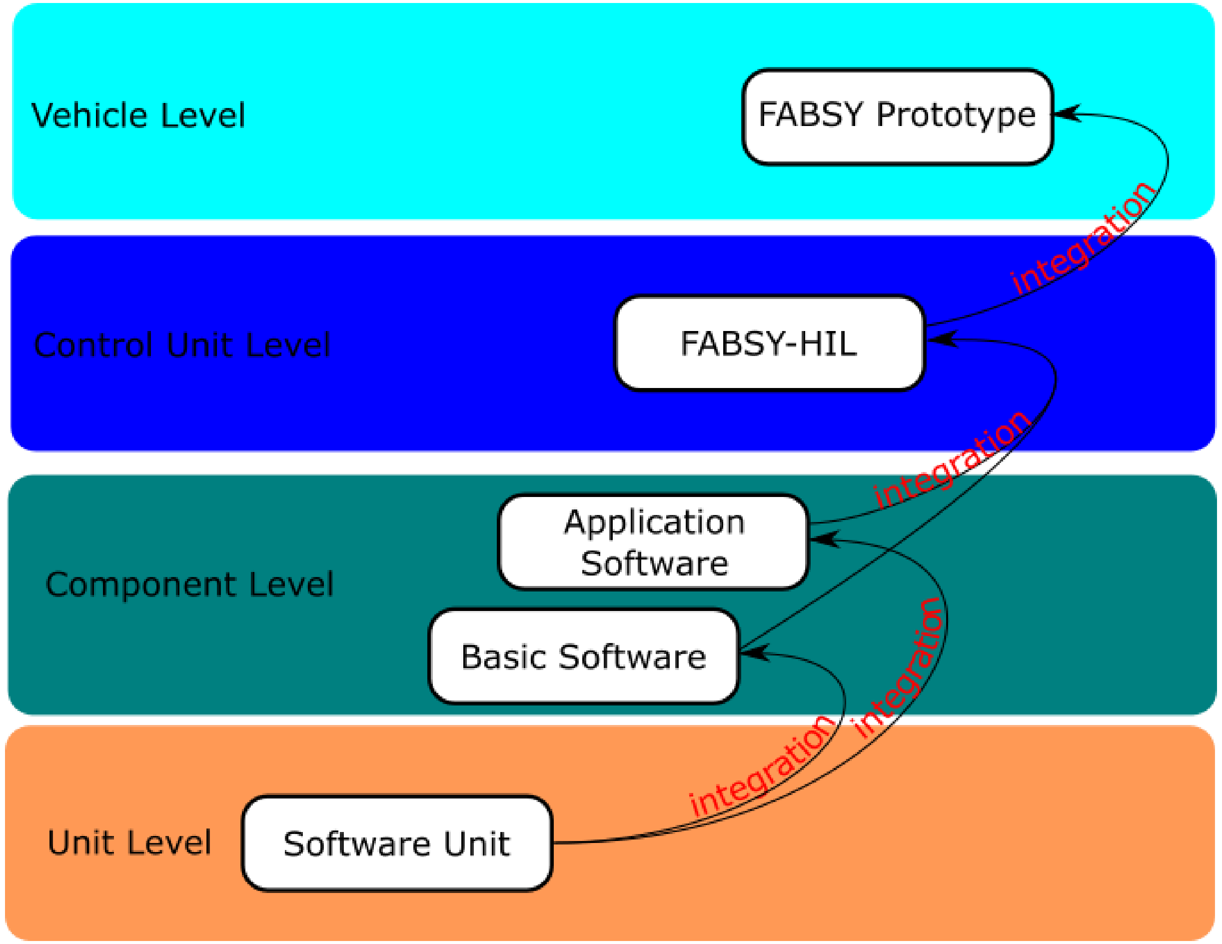
**Bottom-up approach** is pursued in lots of projects, but problematic:

Scheduling is not considered in system design and is
the final step during system integration

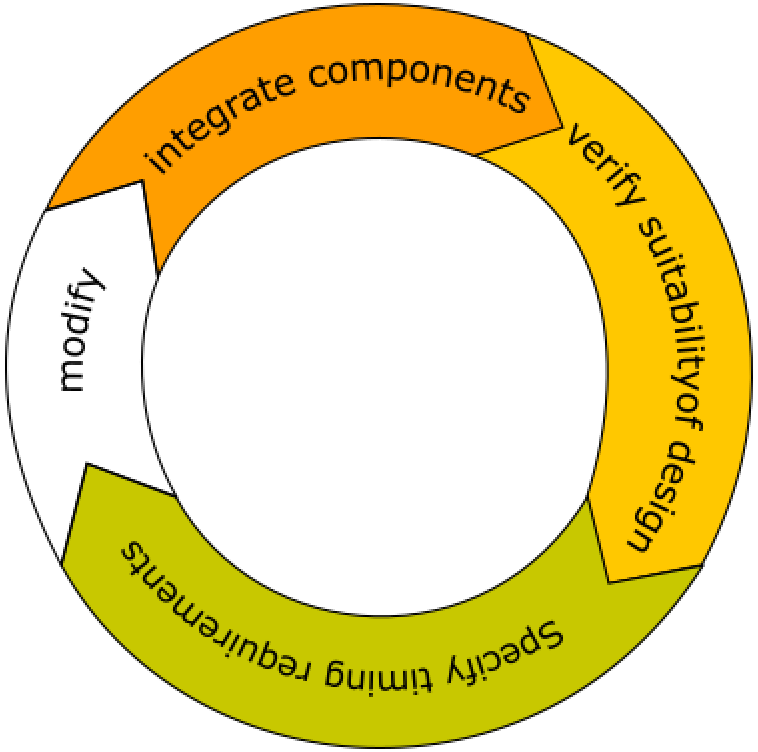
The adherence to timing constraints is strongly dependent on provided components

- Units/components: contain implementation details influencing worst-case execution times
- Application: Mapping of components to tasks and
- jobs (e.g., runnables) to OS threads restrict
- scheduling possibilities

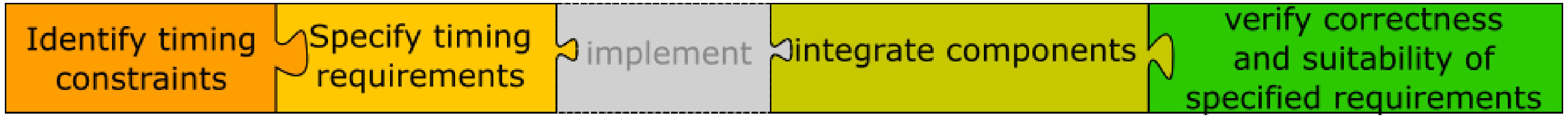
Distributed development and buying software components aggravate the problems imposed by bottom-up approach



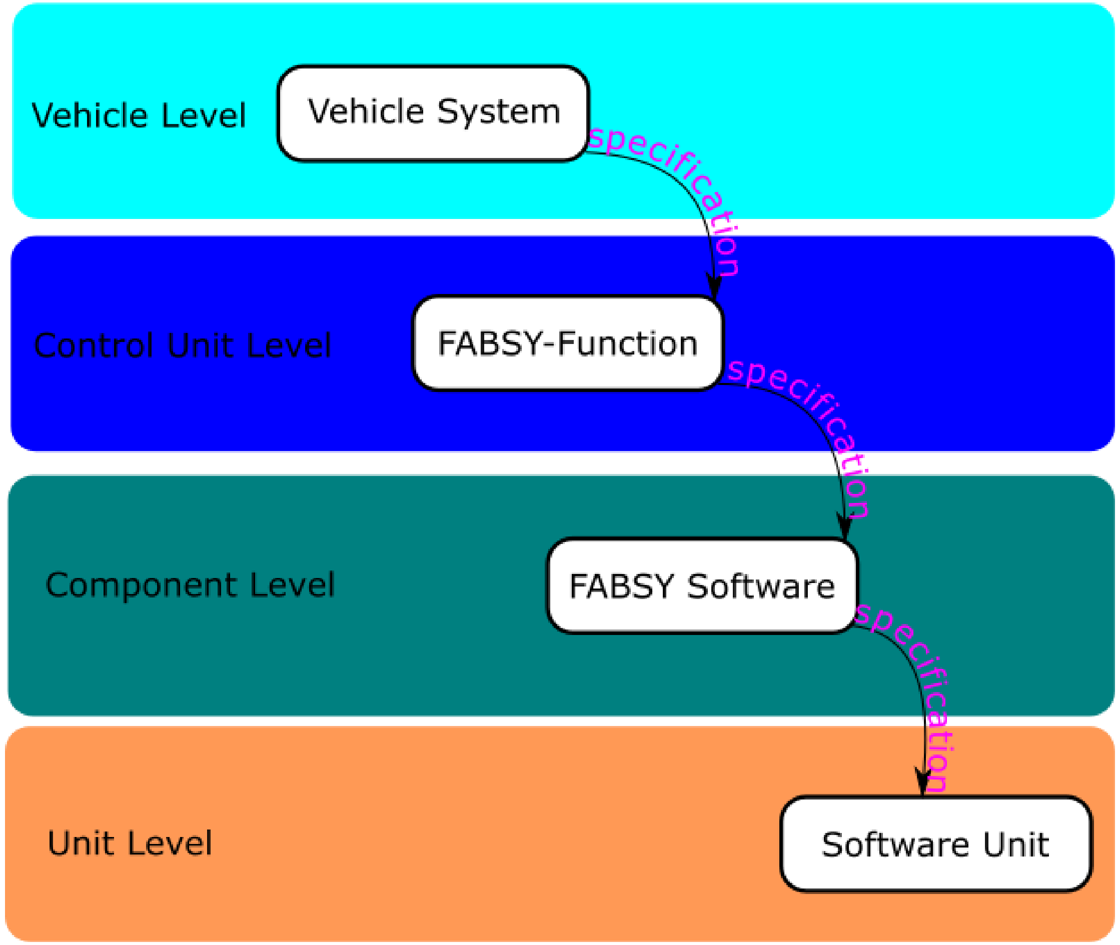
# The result




- Subsequent changes in software units, components and applications are very expensive
- Correction influences execution-time behavior
  - Components' worst-case execution times change
  - Changes in thread mapping aggravate the problem
- Rework may be necessary if a components needs to much CPU time and scheduling fails
  - Inefficient coding
  - Inapt application structure



# How to meet timing requirements




**<u>Top-Down Specification</u>**

- OEM has knowledge about the entire system
- Applications are provided with executions budgets
- Units and components have to use the budgets wisely
- Framework of temporal constraints defines scope of actions

**Q: What is better, bottom-up or top-down?**
**A: Both!**

# Architecture and Real-Time Systems

- Functional architecture is developed with the requirements
- Enables to evaluate the schedulability
- Shows timing requirements and infrastructure
- It identifies and explores alternative implementation strategies consistent with the requirements and risks.

# Architecture and Real-Time Systems

A failure causes the service to deviate from its specified behavior (e.g.,faulty output values). The failure can be caused by an error , that is a discrepancy in the system's internal state and an error (e.g., a deadline is not met) is caused by a faulty assumption (e.g., tasks are not terminated optimally).

System can fail

- Systemarchitecture is designed faulty
- Timing requirements are not derived properly

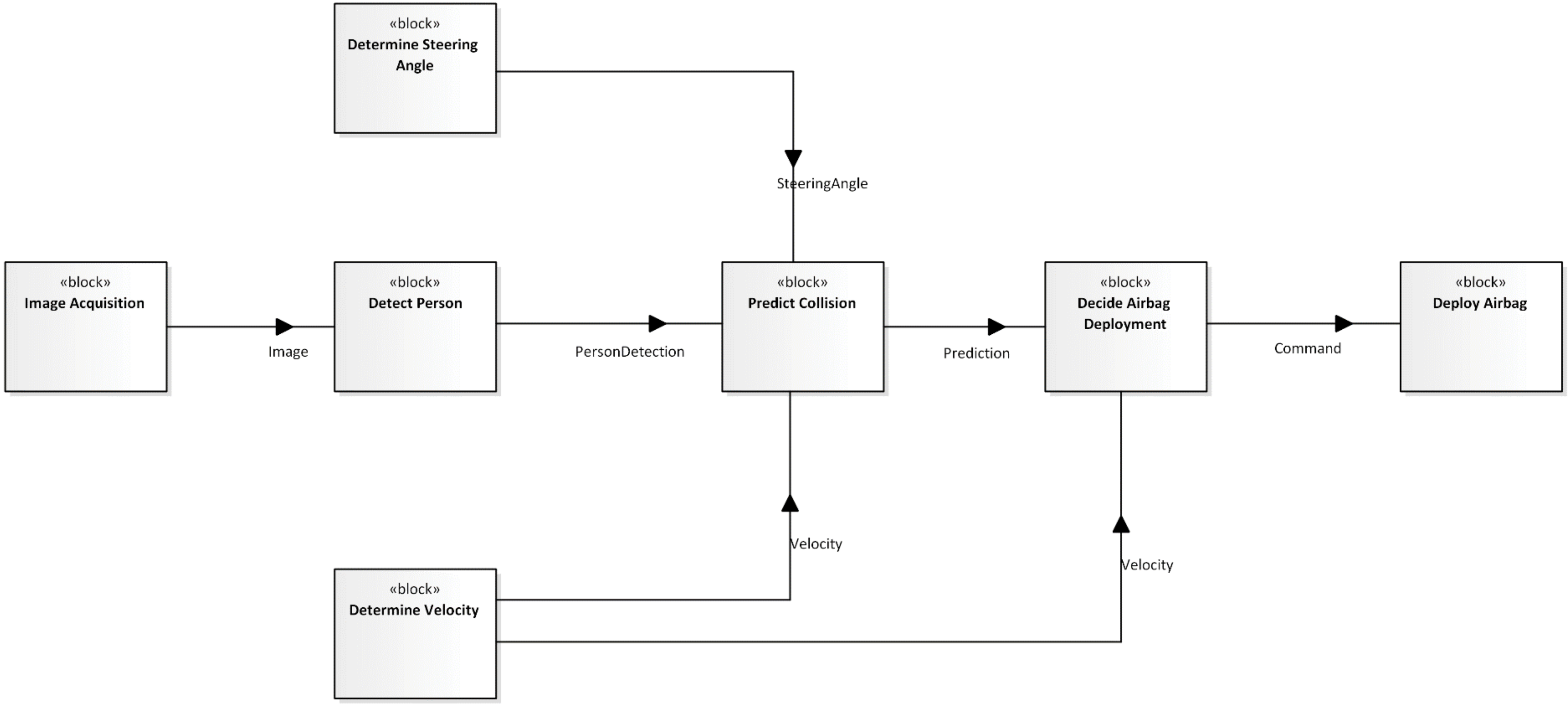
Hardware can fail

- Caused by random faults (see HW-Metrics)
- Caused by systematic faults: bugs
- Caused by system specification/design faults
- etc.

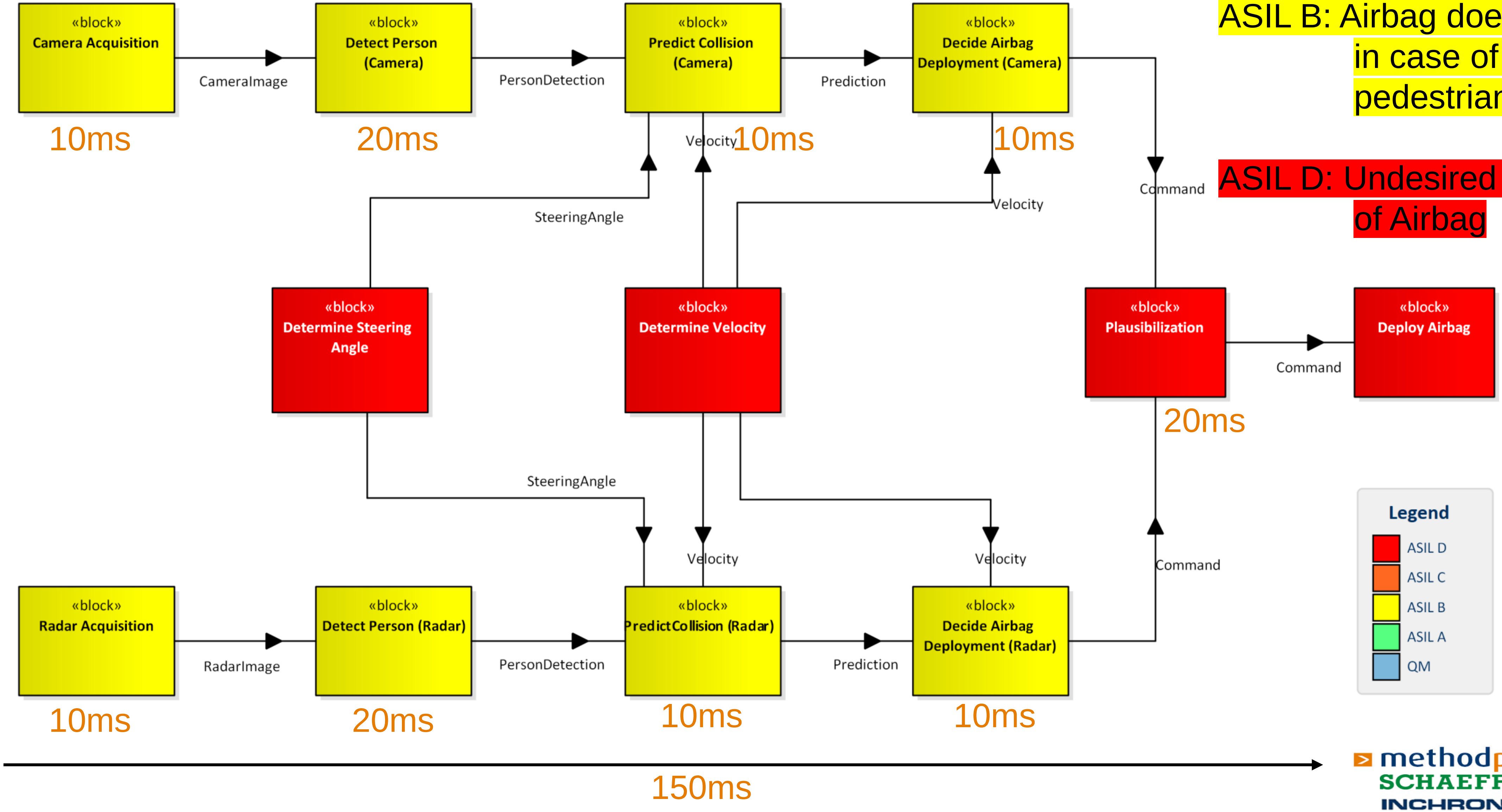
Software can fail

- Caused by systematic failures in software
- Caused by hardware failures
- **Caused by system specification/architecture faults**
- etc.

# FABSY – Preliminary architectural assumption



# FABSY – Functional Architecture

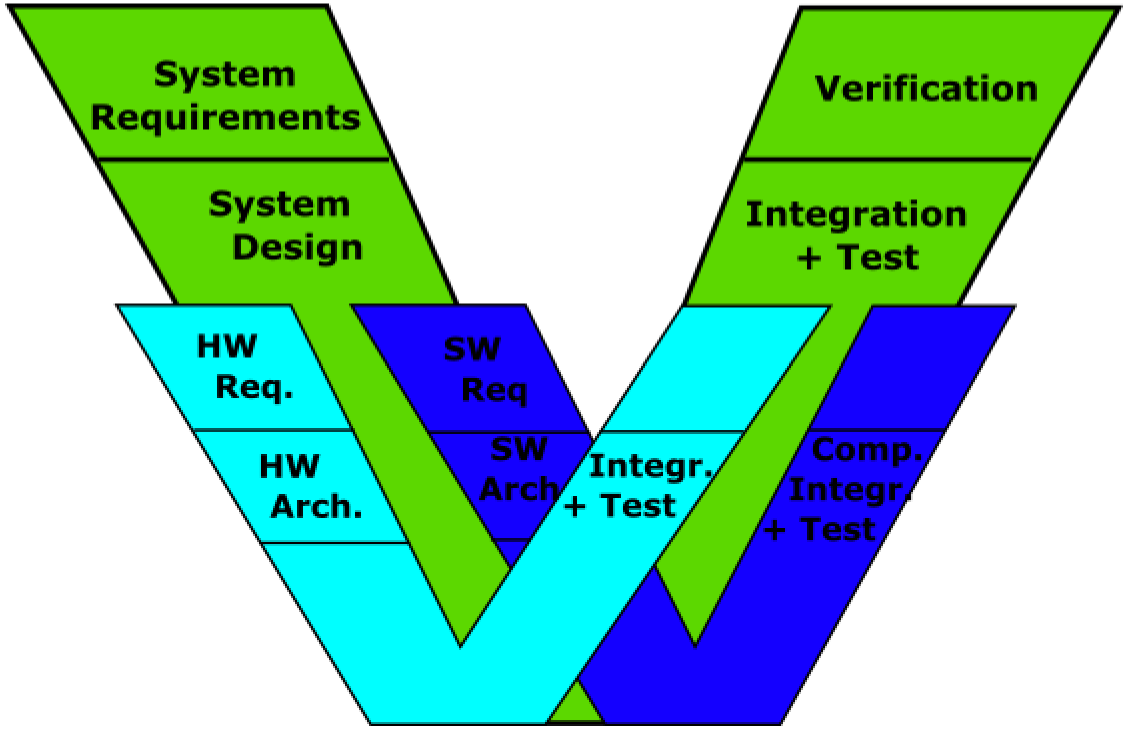



ASIL B: Airbag does not inflate in case of crash with pedestrian

ASIL D: Undesired activation of Airbag

# Fighting timing faults

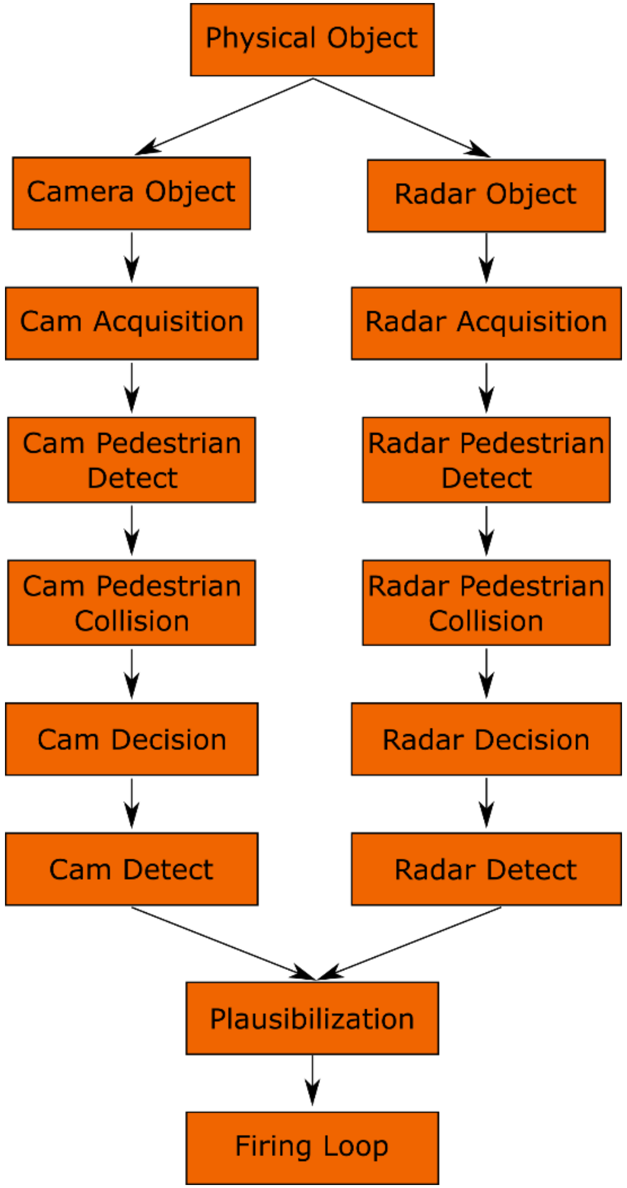
**Finding systematic timing faults at its root and not just dealing with the effects.**




**Timing faults origin in:**

- System design
- SW-Architecture
- HW-Architecture

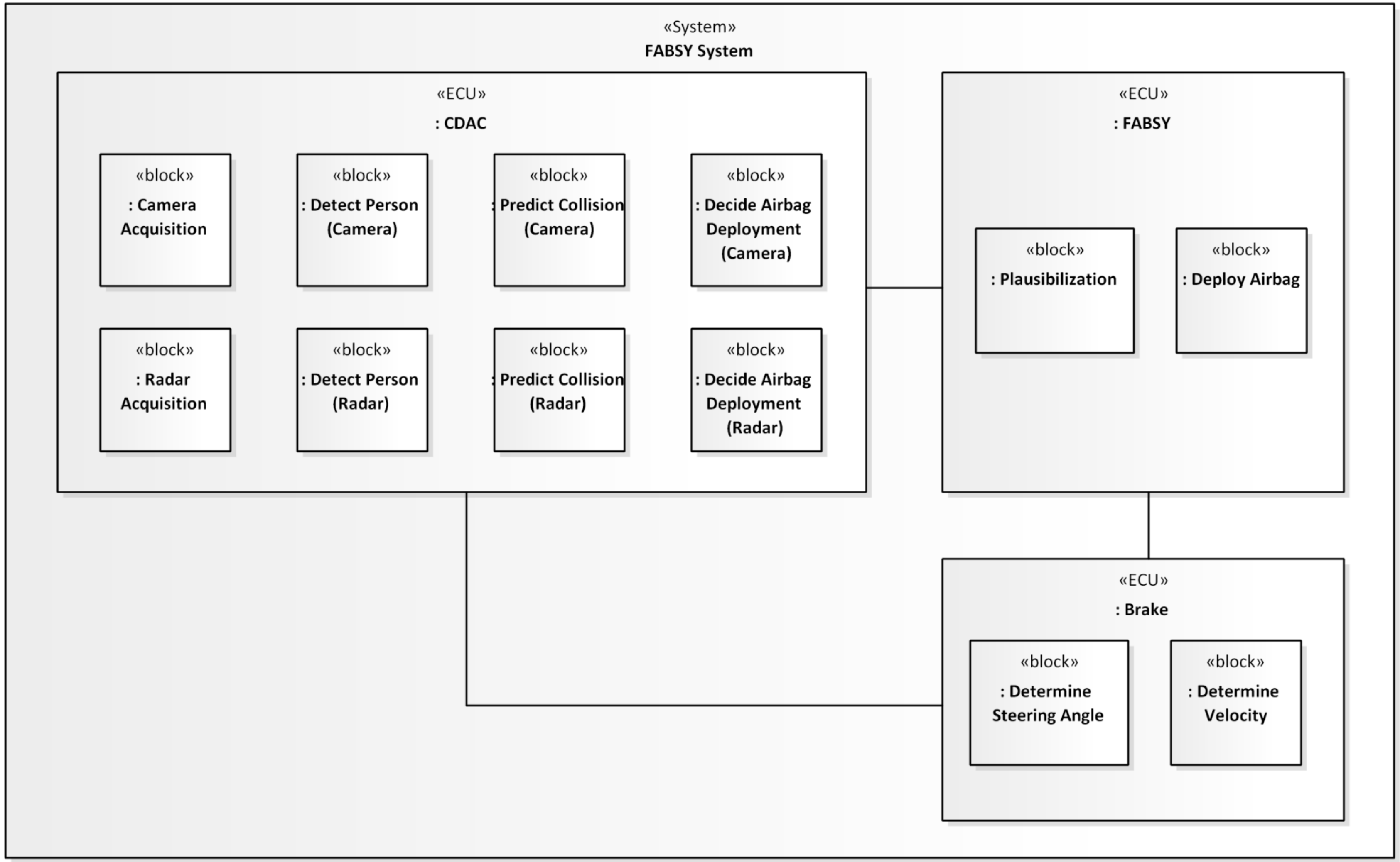
# FABSY – Effect Chain



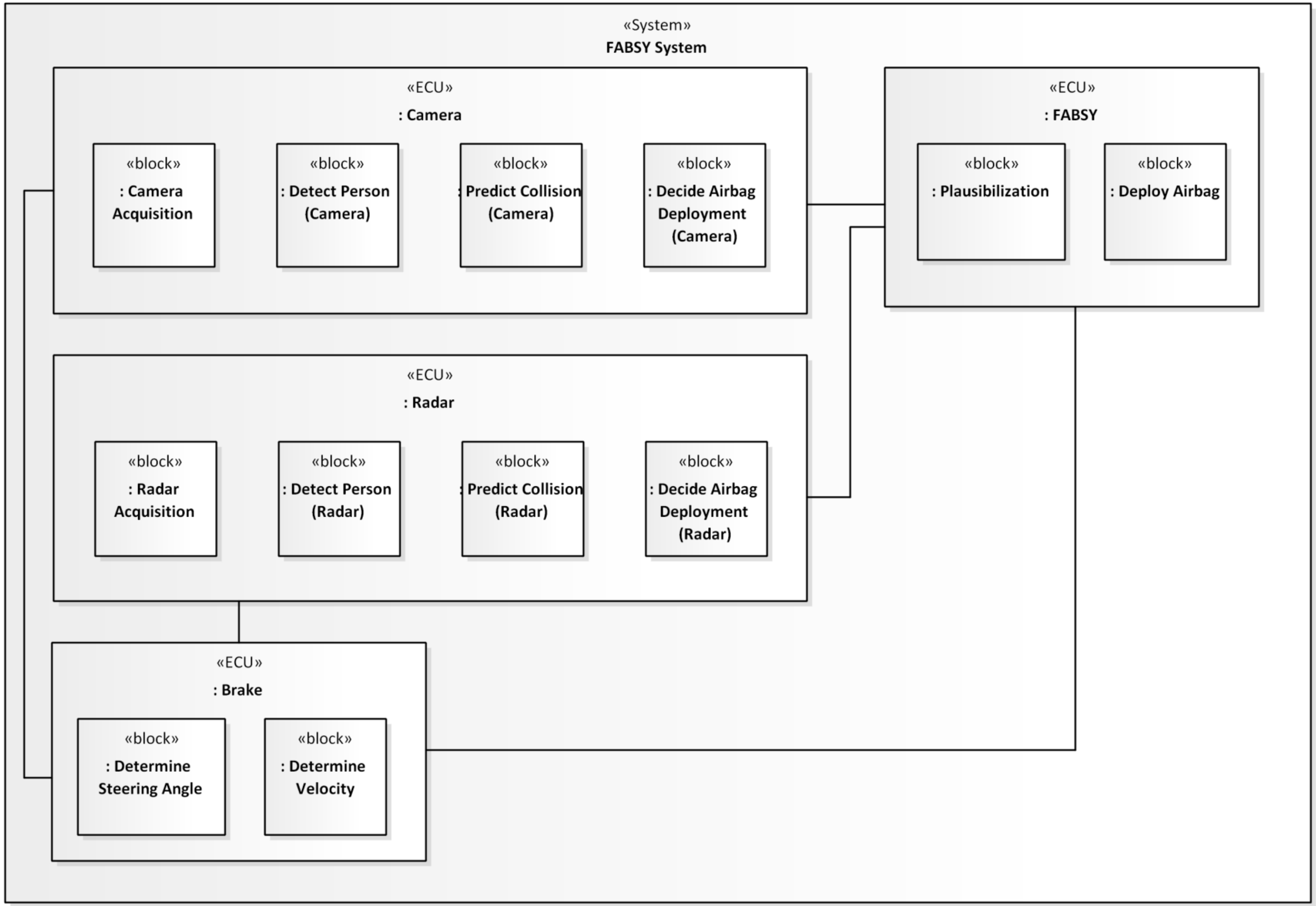

The functionality has to be allocated to control units

Transmission paths depending on technology (LIN, CAN, Flexray, …) and distance cause further delay an have to be considered → architecture of the onboard electrical system (Bordnetzarchitektur)

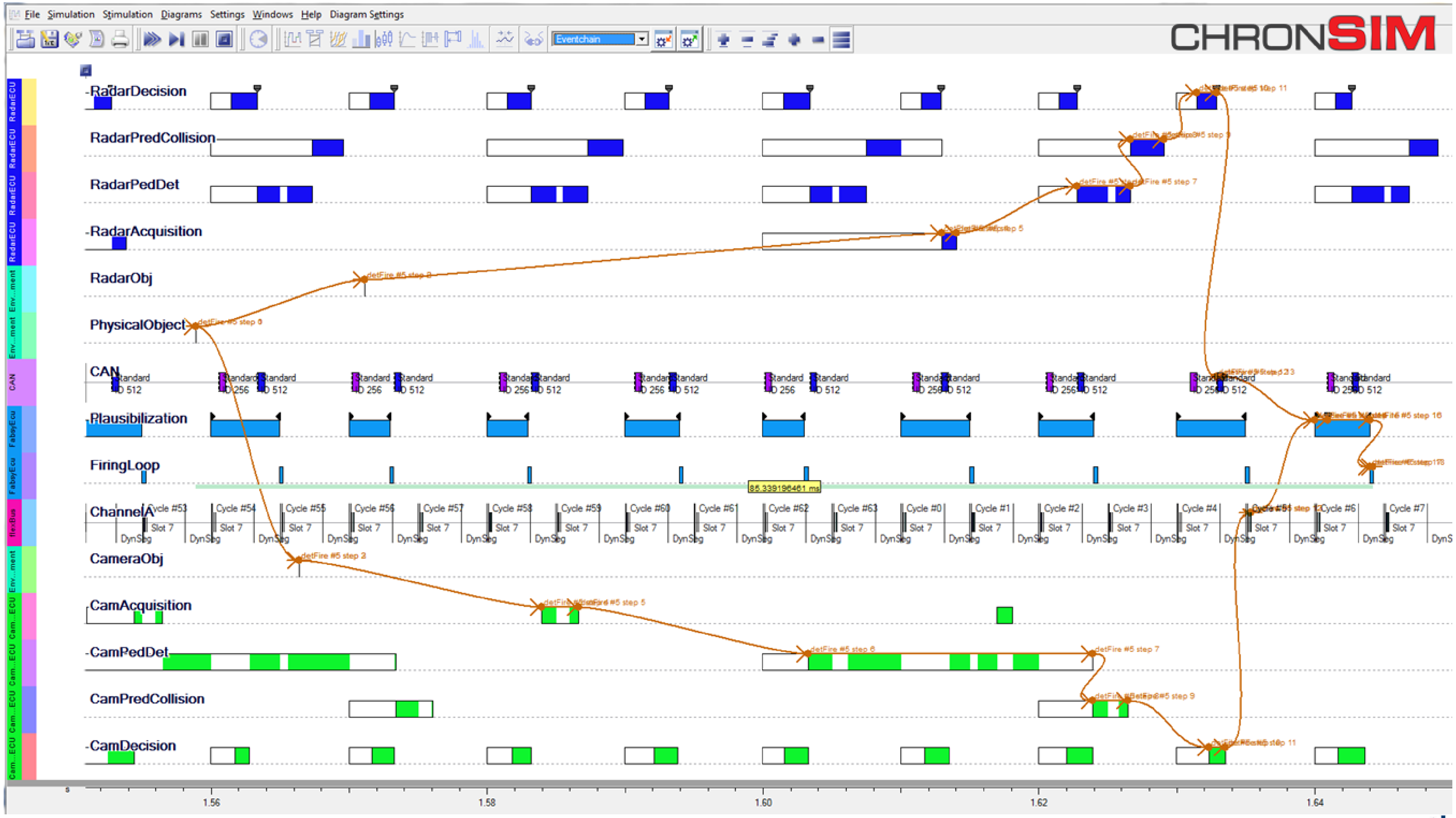
# FABSY – Technical Architecture



# FABSY – Technical Architecture



# FABSY – Evaluation of Architecture

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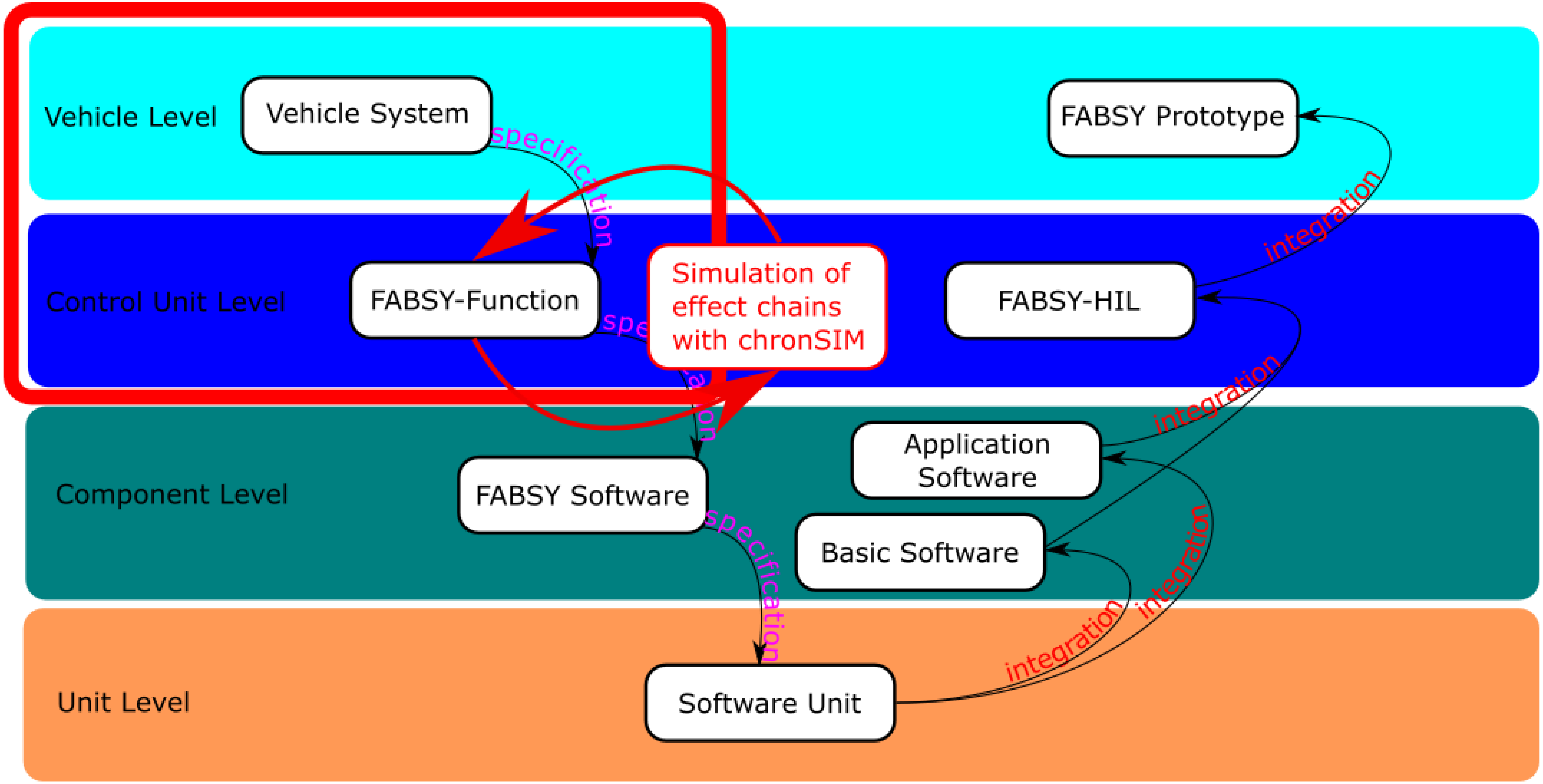
# Evaluation of Architecture – The Tool

- Ereignisgesteuerte Simulation mit Zeitbasis
- Scheduler simuliert das ausführen von Tasks, Runables, …
- Tasks werden aktiviert, unterbrochen, wiederaufgenommen
- Anzahl von Cores, Taktzeit, busspezifischen Übertragungszeiten können berücksichtigt werden
- Asychronität von zb.: Flexray und µC kann miteinbezogen werden

- Datenfluss in Wirkketten wird grafisch dargestellt


Vehicle Level
Vehicle System
FABSY Prototype
specification
integration
Control Unit Level
FABSY-Function
Simulation of effect chains with chronSIM
FABSY-HIL
integration
Component Level
Application Software
FABSY Software
Basic Software
specification
integration
integration
Unit Level
Software Unit

# The result

- Timing budgets are defined and assigned
- Architecture is designed
- Architecture is evaluated based on assigned budgets

- Established methods still need to be carried out (code checking, watchdogs, integration tests, ..) but will cause less effort

# In case of questions

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