SYMTA VISION

The AUTOSAR Timing Model

Status and Challenges

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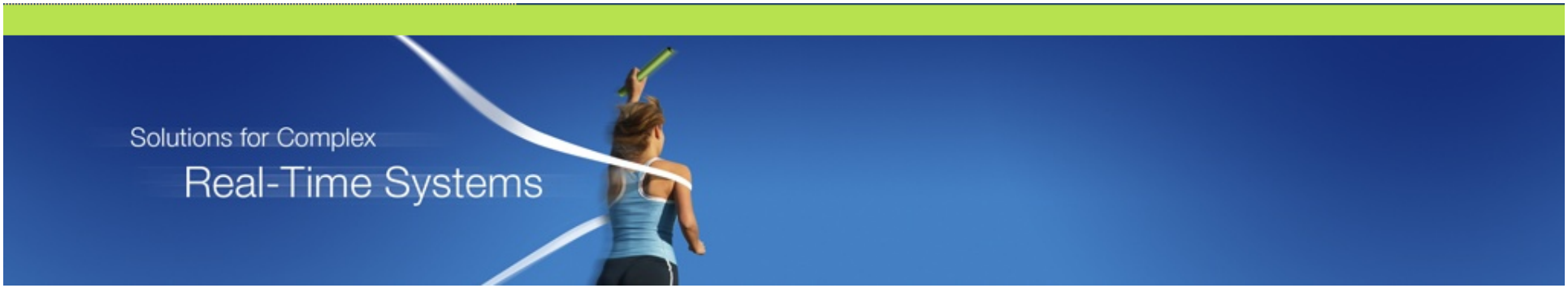
Symtavision GmbH, Germany

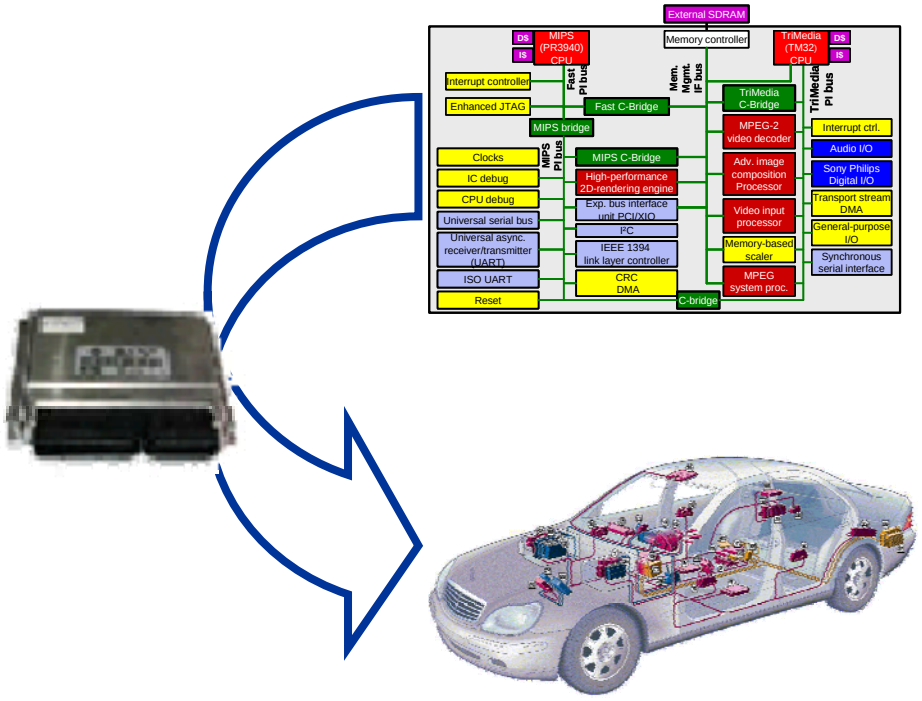


Symtavision GmbH – Who we are !

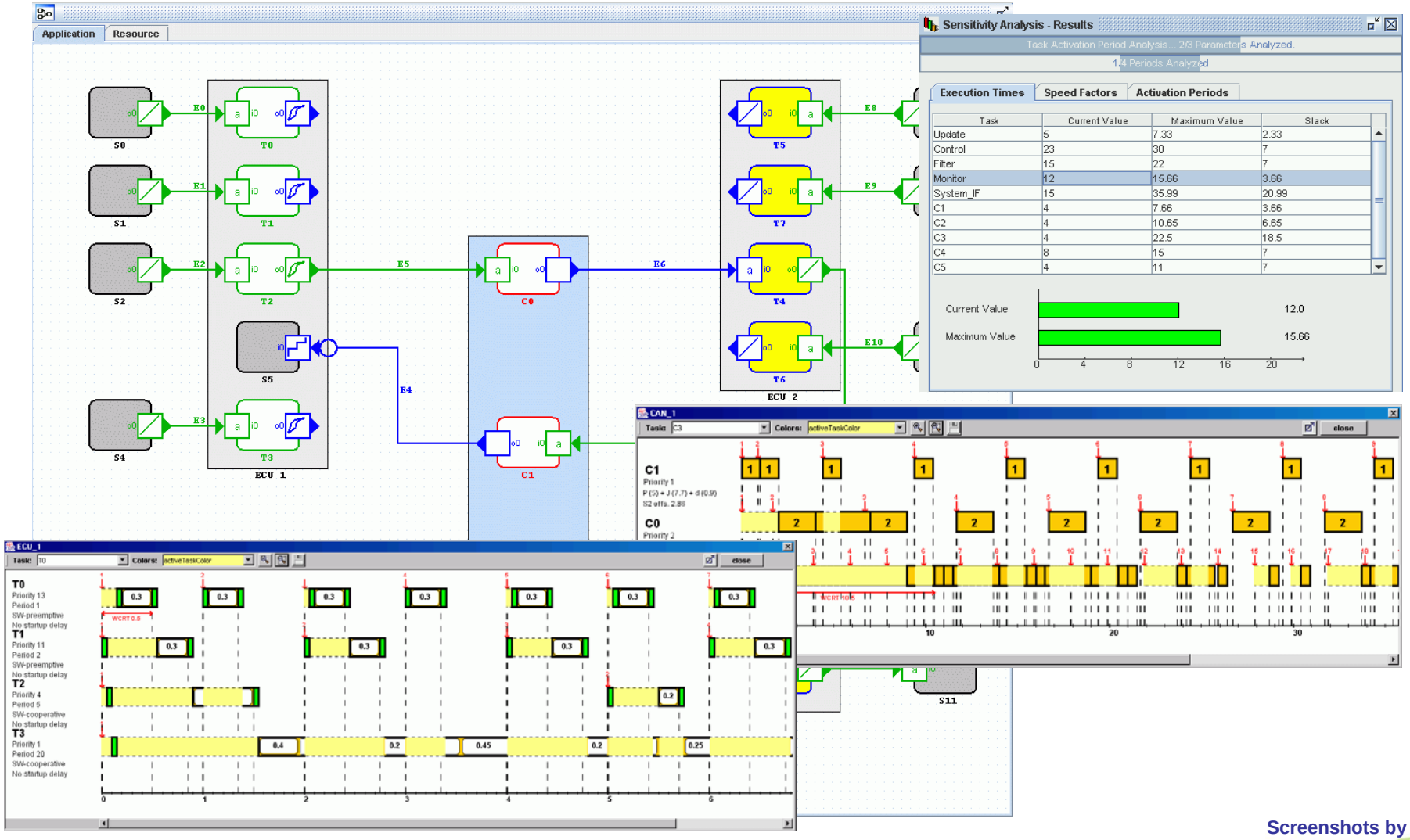
- Spin-off from Technical University of Braunschweig, Germany, founded May 2005
- Timing and scheduling analysis tool suite SymTA/S
- 30+ MY research and development of technology
- Expertise in system integration
- Primary market: Automotive

Symtavision Expertise: Real-Time Systems Analysis

- Real-time correctness ➔ Reliability / Dependability
- Optimization ➔ Cost
  - component selection
  - dimensioning
  - scheduling
- Flexibility ➔ Quality



Solution: Flexible, Modular SymTA/S Tool Suite



Screenshots by SYMTA

Overview

- AUTOSAR in general & target use cases
- Top-down: SW architecture vs. execution platform
- A closer look to key technical details
- Bottom-up: Integration & timing analysis practice
- Implications w.r.t AUTOSAR goals
- Conclusion

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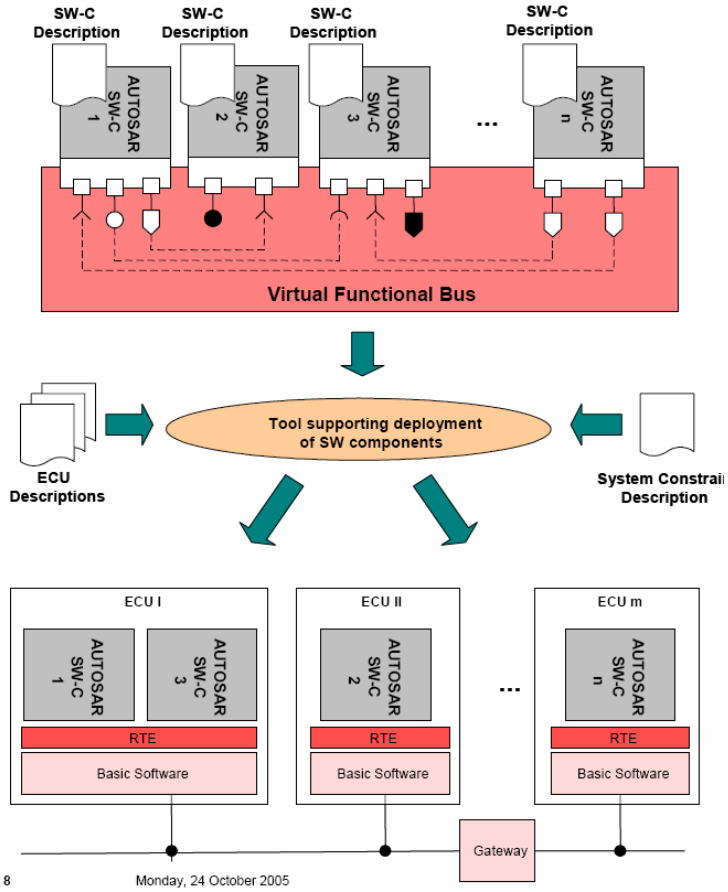
Key AUTOSAR Concepts

- portable software components
- virtual function bus (VFB)
- ports and connectors
- several communication semantics (send/recv, client/server)
- crossing module boundaries (function distribution)
- crossing company boundaries (supply chain, black box)
- configurable/customizable run-time environment

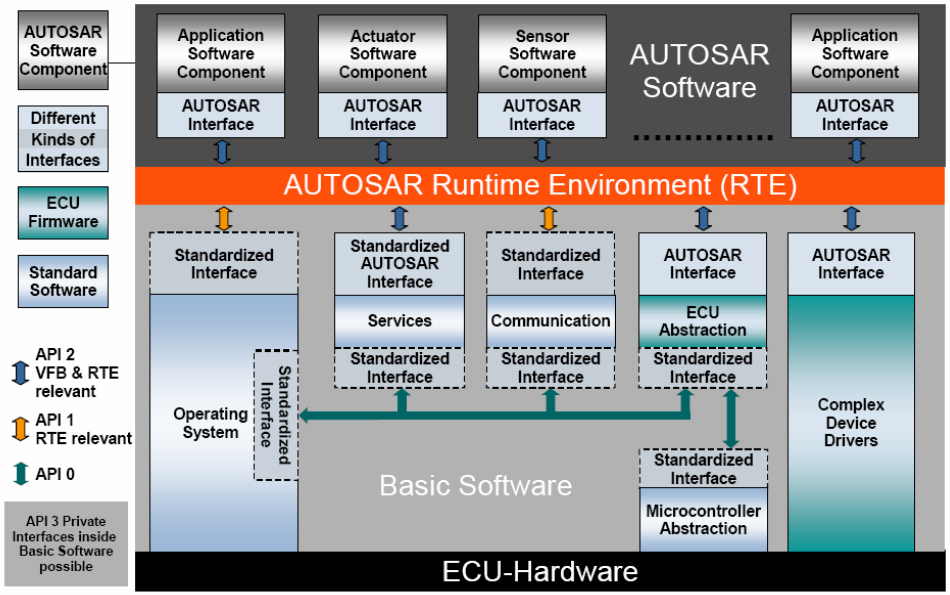
➔ Needs standardized APIs to facilitate implementation!

Key AUTOSAR "Methodology and RTE"

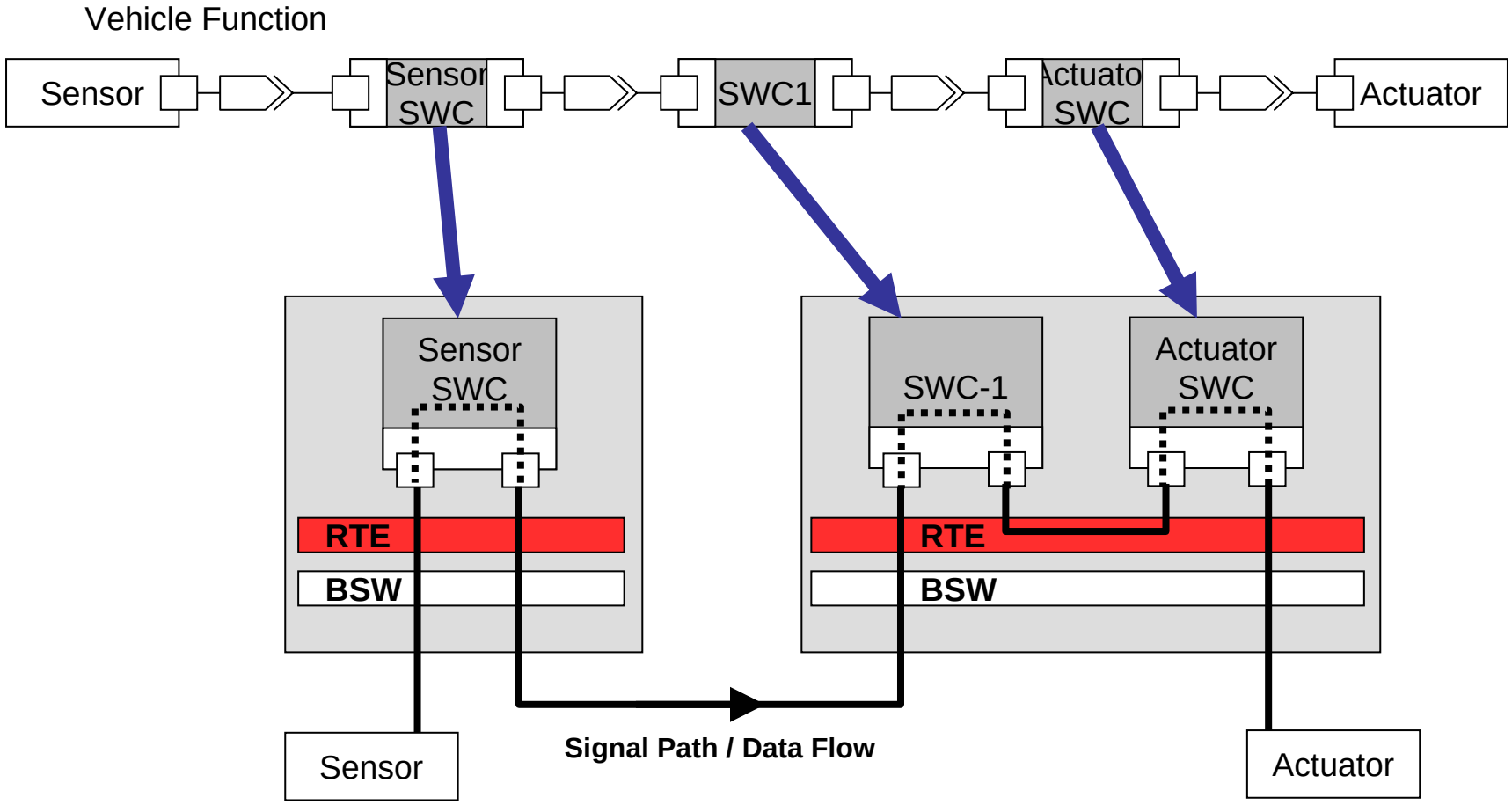
- Flexible mapping of software components ...



- ... enabled by standardized run-time environment (RTE)



Mapping in More Detail: SW Component Structure and Execution Platform



- Standardized RTE eases compiling & linking together several SW components from different teams/vendors/...

Typical AUTOSAR Use Cases

- Function distribution & partitioning
  - one function - several SW components one several ECUs
  - one ECU - several SW-Cs from different functions / vendors
- Adding new functions
  - product variants, face lifts, platforms
- Optimizations
  - Configuration (CAN IDs, signal-to-frame assignment, etc.)
  - Re-mapping of SW components
  - Network modifications (topology, protocols, gatewaying)
- New business models
  - Software as a product
  - Improved supply-chain "contracting" (liabilities)

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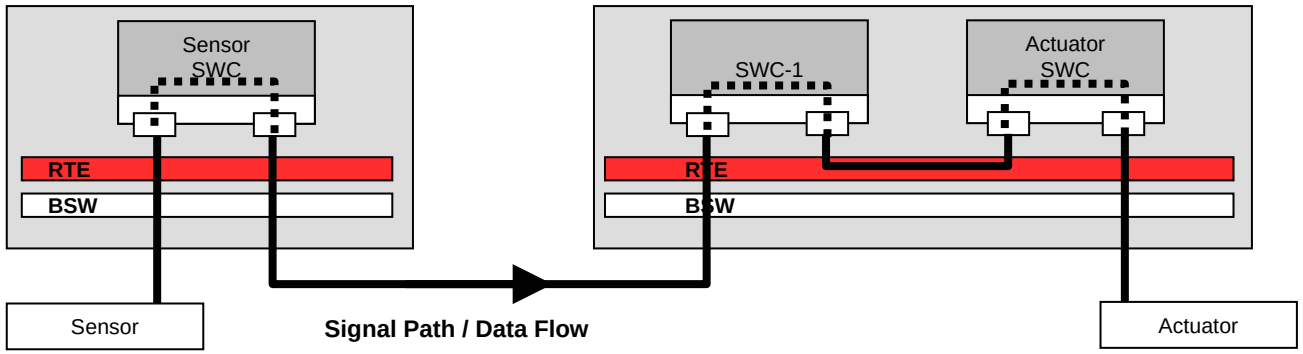
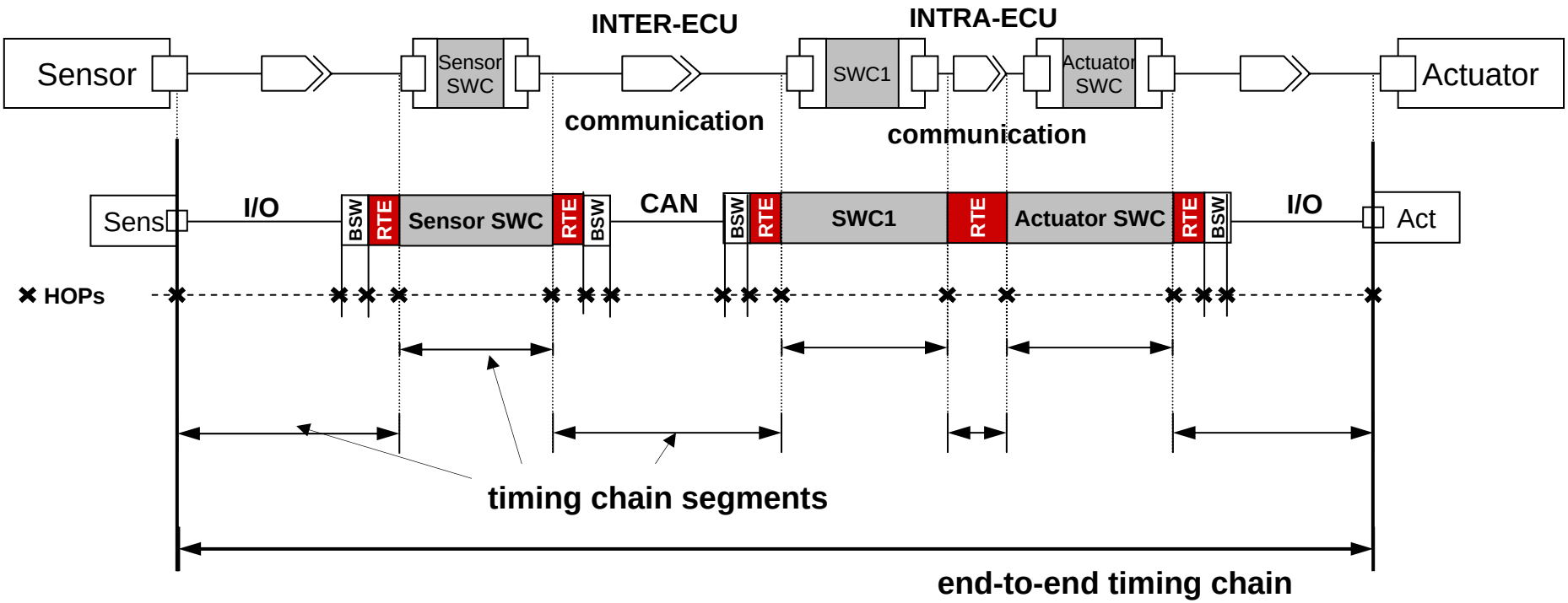
Introduction of Timing Effects: Framework

- Function development imposes timing constraints
- High-level specification based on SW components
- AUTOSAR goal: break down the software structure into "manageable" blocks
  - timing chains and timing chain segments
  - connected at hand-over points (HOPs)
  - consider each segment / HOP individually
- Goals:
  - divide and conquer "timing analysis" top-down
  - assignment of responsibilities
  - locally verifiable, then result composition bottom-up

Timing Chains and Hand-Over Points (HOPs)





Introduction of Local Timing Effects

- Reasoning about timing requires considering two views:
  static **software components**
  vs. dynamic **execution platform** behavior
  - operating systems and scheduling;
    SW components vs. runnables and tasks
  - communication semantics;
    SW-C structure vs. timing dependencies
  - middleware / driver structure;
    standardized protocols vs.
    non-standardized implementation & BSW

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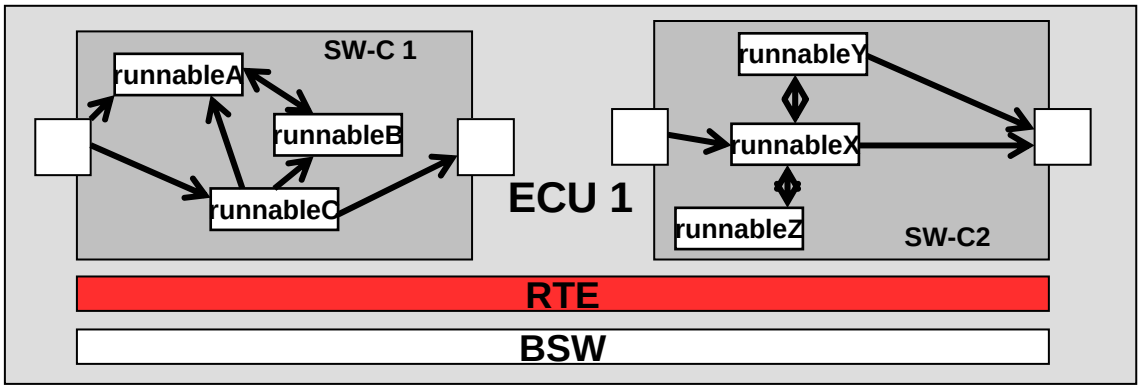
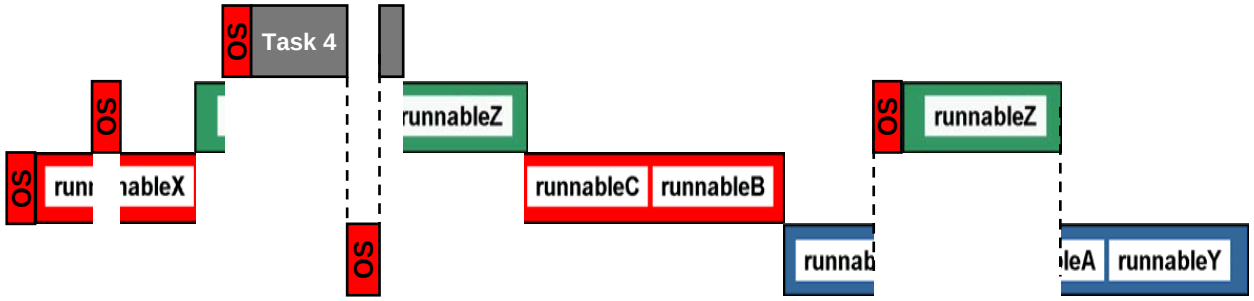
SW-Components vs. "Runnables" and Tasks

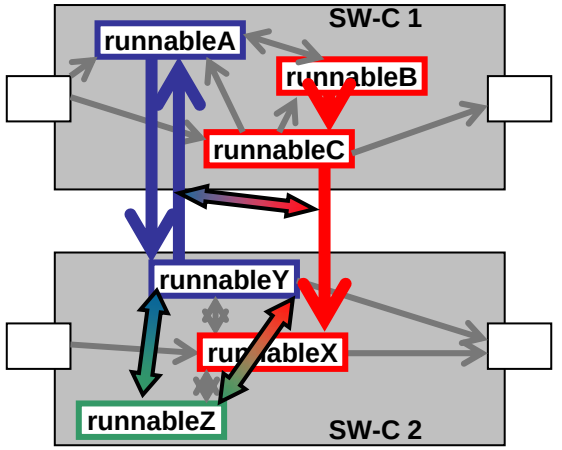
- SW architecture:
  2 SW components,
  6 runnables



- Implementation: 3 Tasks

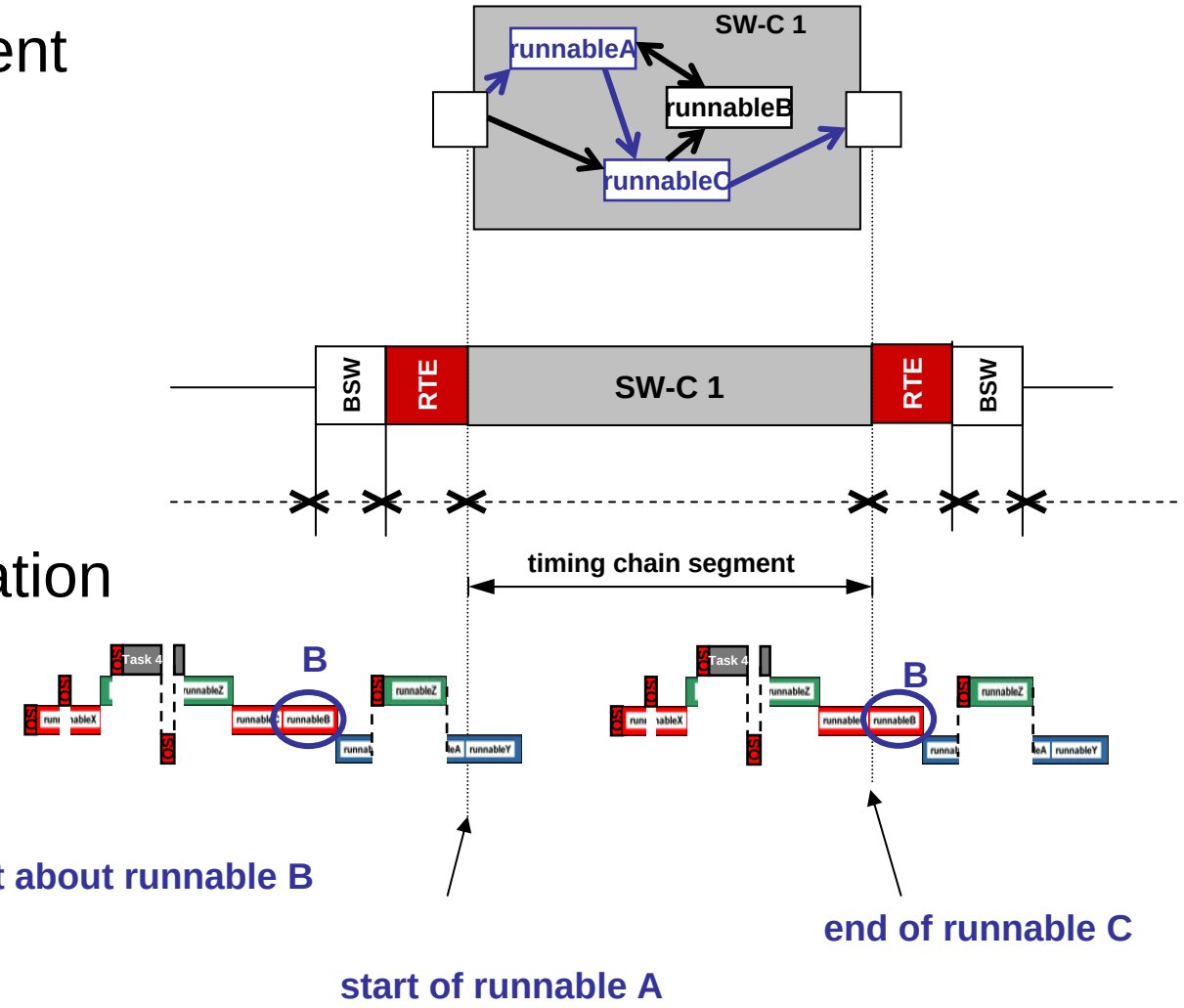
- Schedule and timing dependencies





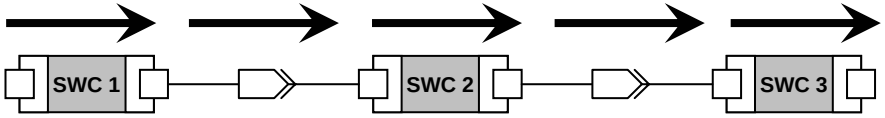
Challenge:
Associating Schedules with Timing Chain Segments

- software component w/ 3 runnables
- sequential model
- actual implementation
- ***meaning ?***

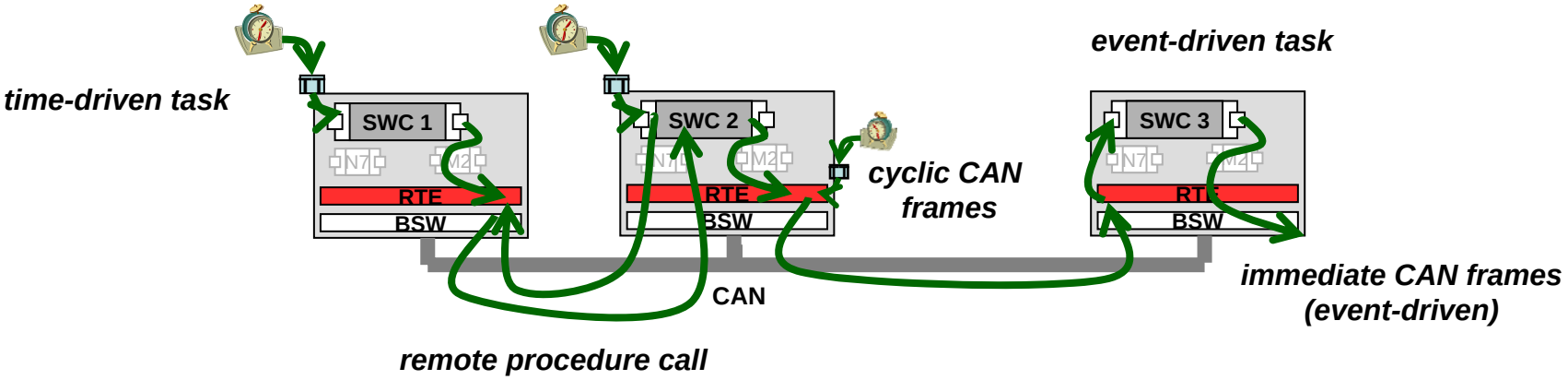


Software Component Structure vs. Timing Dependencies

- Software component view captures "logical" dependencies (data flow)



- Implementation timing dependencies can be very different!!!
  - time-driven and event-driven activation
  - send/recv and client/server communication (remote procedure call)
  - over- / undersampling



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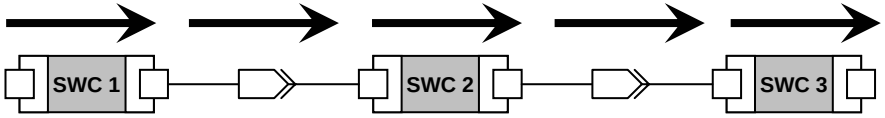

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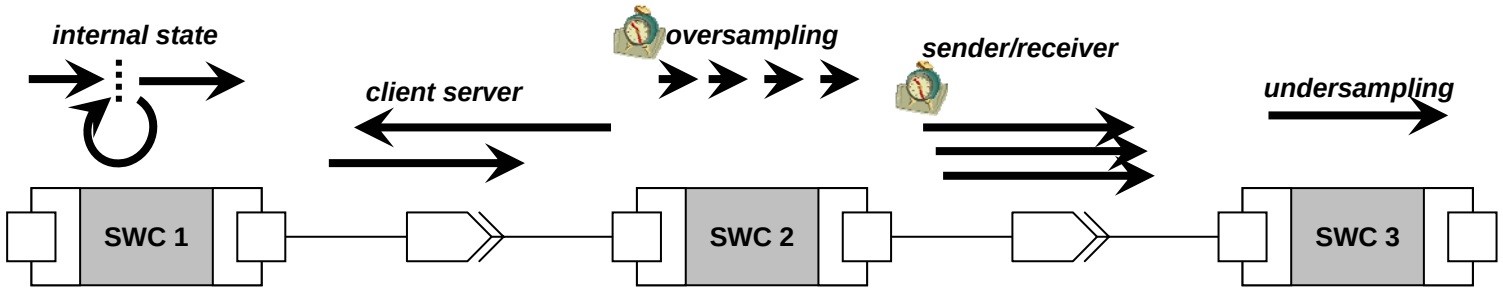
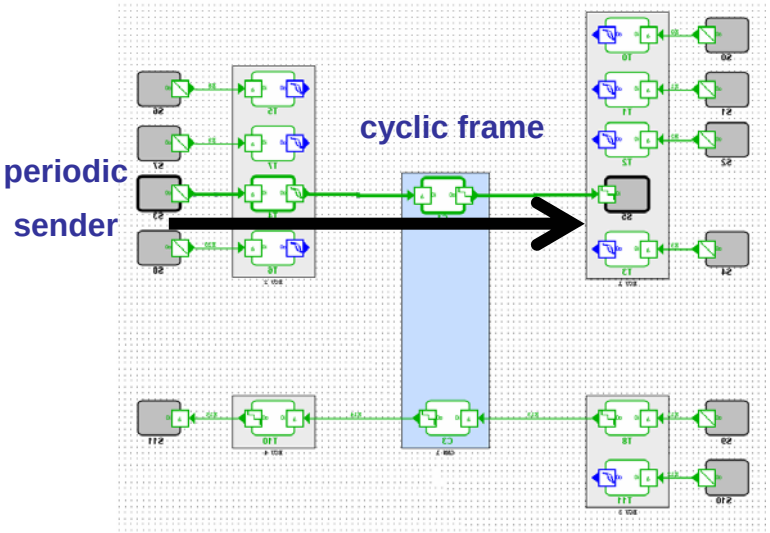


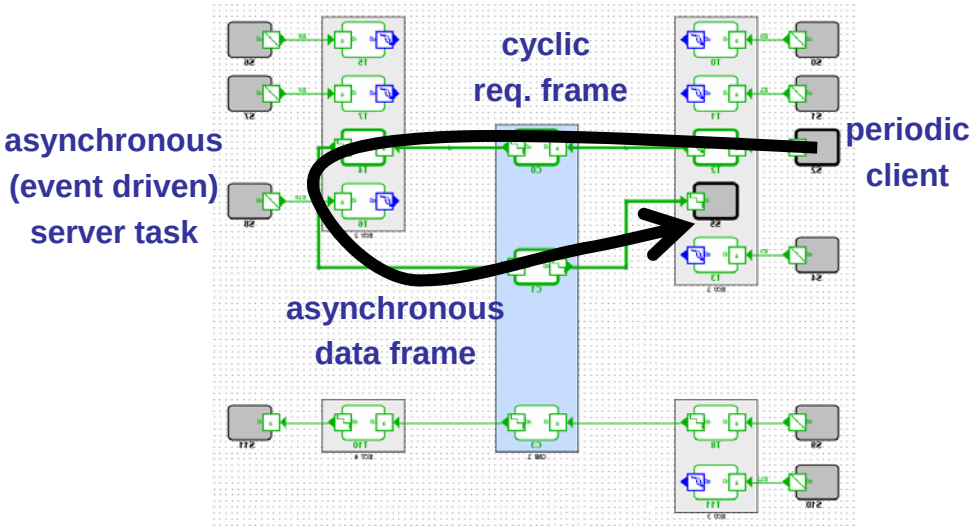
Sender-Receiver vs. Client-Server I

- INTRA-ECU communication: both SW-Cs on one ECU
  - merely an issue of software structure
  - global register vs. local variable (with get Method)

- INTER-ECU communication: SW-Cs on different ECUs
  - has large influence on bus / ECU timing



sender-receiver

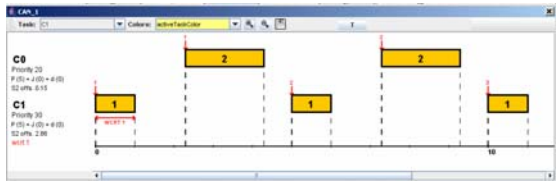


client-server

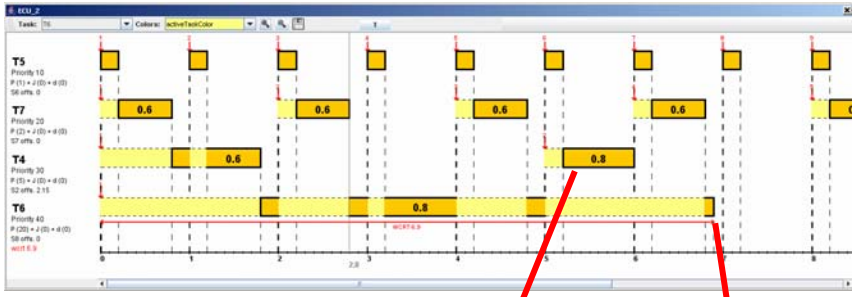
Screenshots by SYMTA

Sender-Receiver vs. Client-Server II

- sender-receiver w/ cyclic tasks and frames

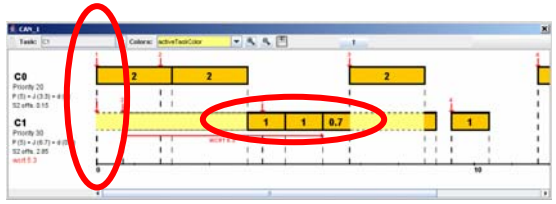


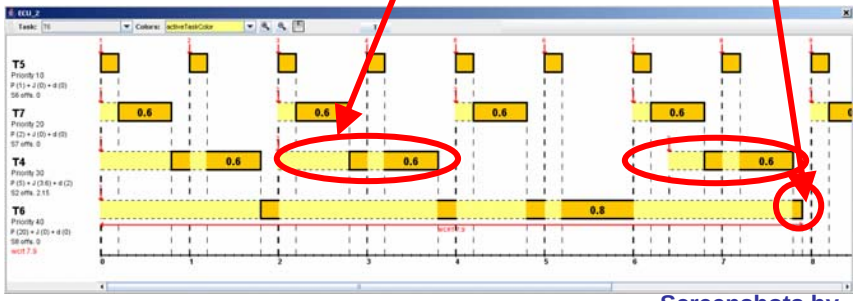
bus message timing



ECU 2 timing

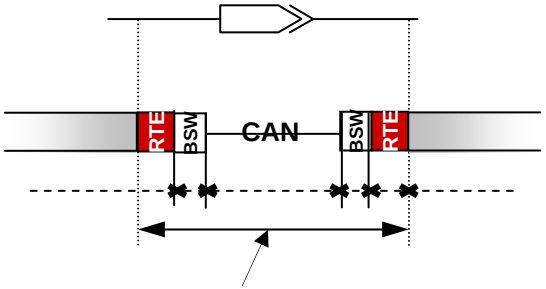
- client-server solution w/ asynchronous servers and frames





Screenshots by SYMTA

Protocols vs. Non-Standardized BSW



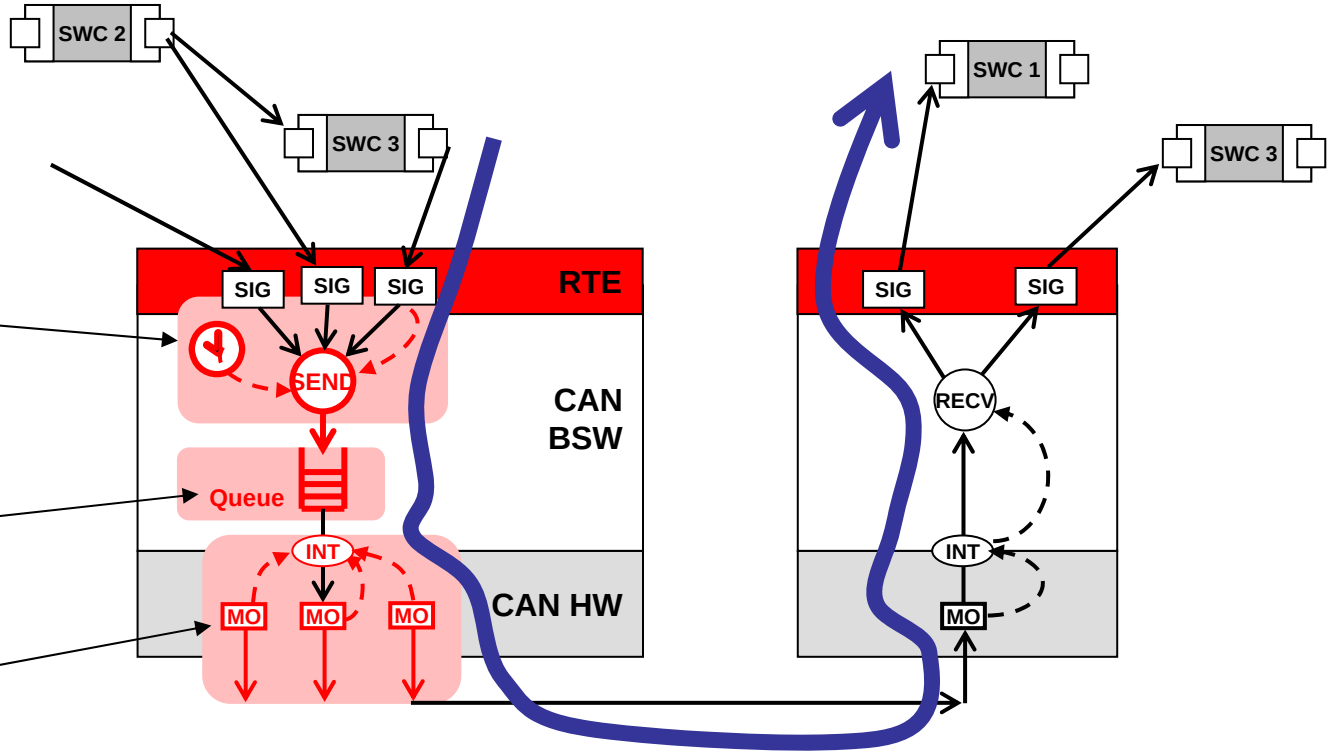
COM timing chain segment

SIG	signal register
SEND/ RECV	COM layer tasks or interrupts
INT	driver interrupt
MO	message object (HW buffer)

Frame generation timing (cyclic and/or event+driven)

Buffering strategy (FIFO, priority ordered, hybrid)

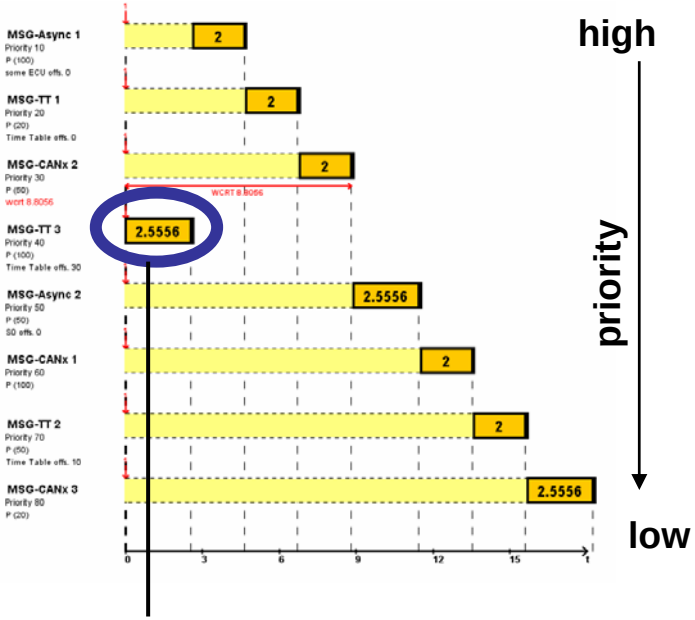
Use of message objects (hardware buffers)



Priority Queue vs. FIFO in CAN Networks

- buffering strategy (inside ECU) has huge influence on network timing

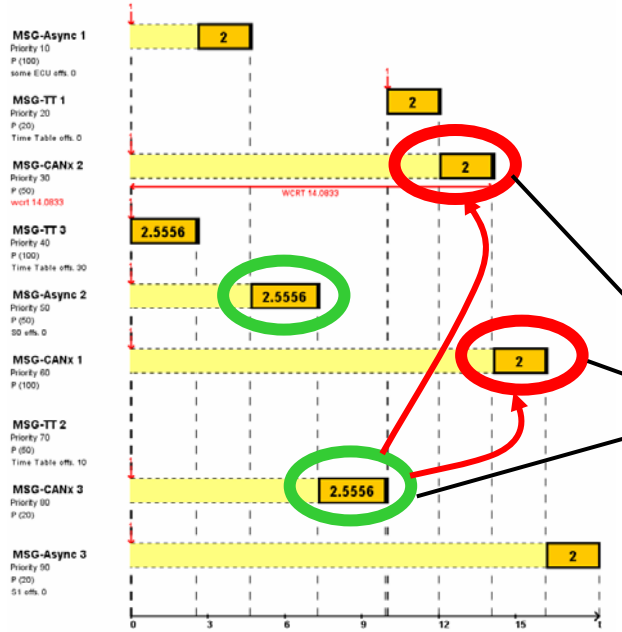
Shared priority-ordered buffer



blocking due to non-preemptiveness

Shared FIFO Buffer

undermines the CAN protocol's priority scheme



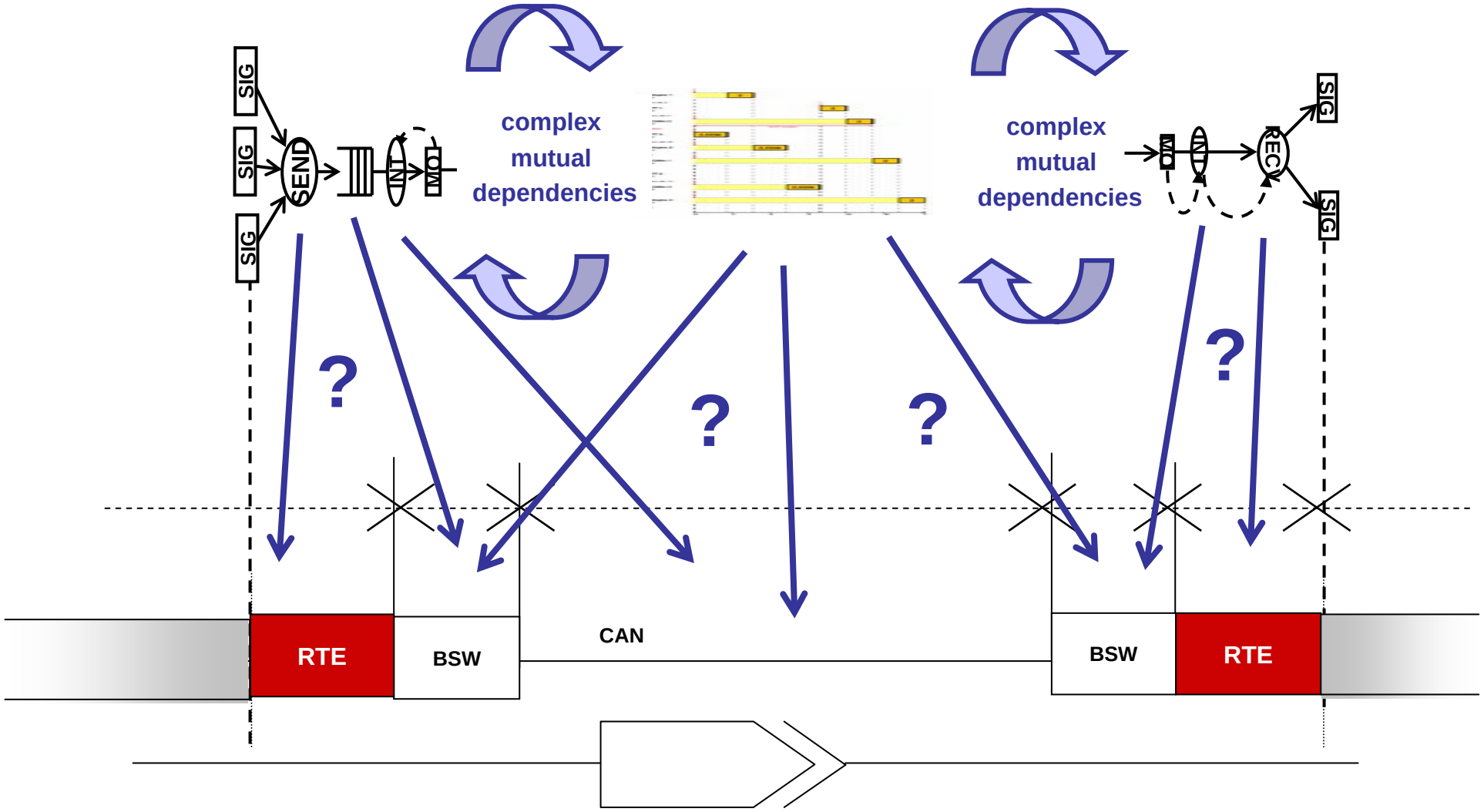
3 messages share a FIFO

low-priority frames benefit from FIFO

high-priority frames must wait for low-priority frames

Screenshots by SYMTA

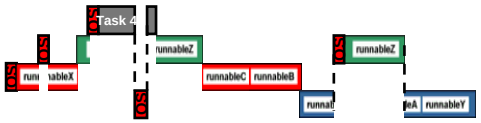
Challenge:
Associating Schedules with Timing Chain Segments



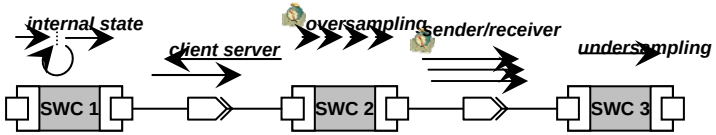
Summary: Local Timing Effects

Complex timing

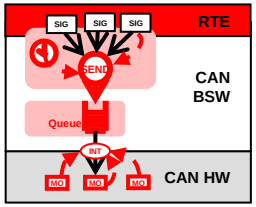
- is not directly reflected in the **software architecture**
- is induced by the **execution platform!**
  - runnables and tasks



  - timing dependencies and communication semantics



  - non-standardized drivers and middleware (BSW)



- etc...

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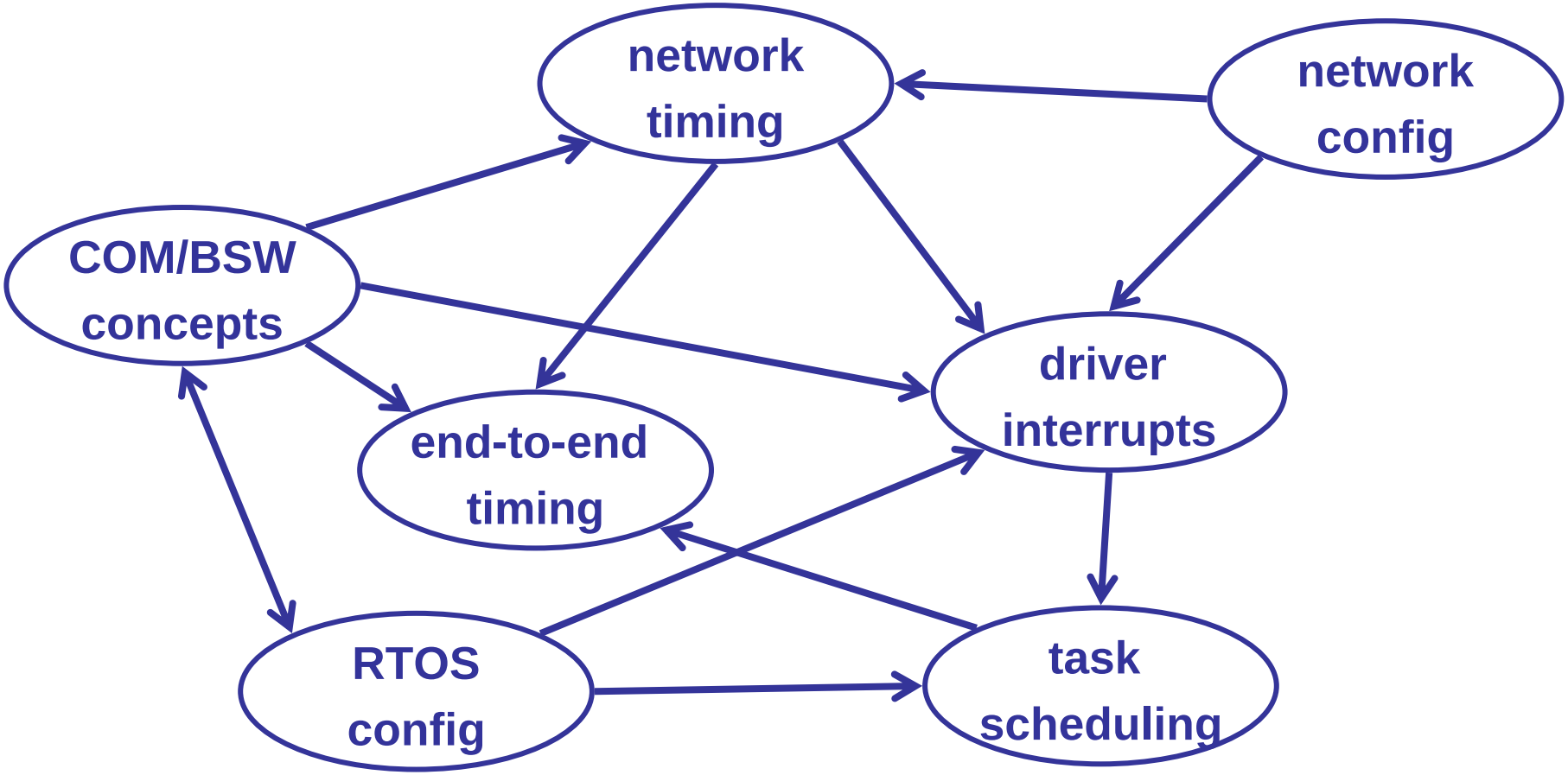
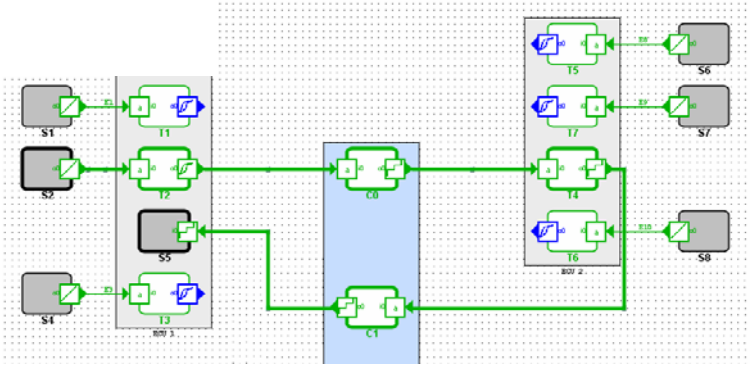
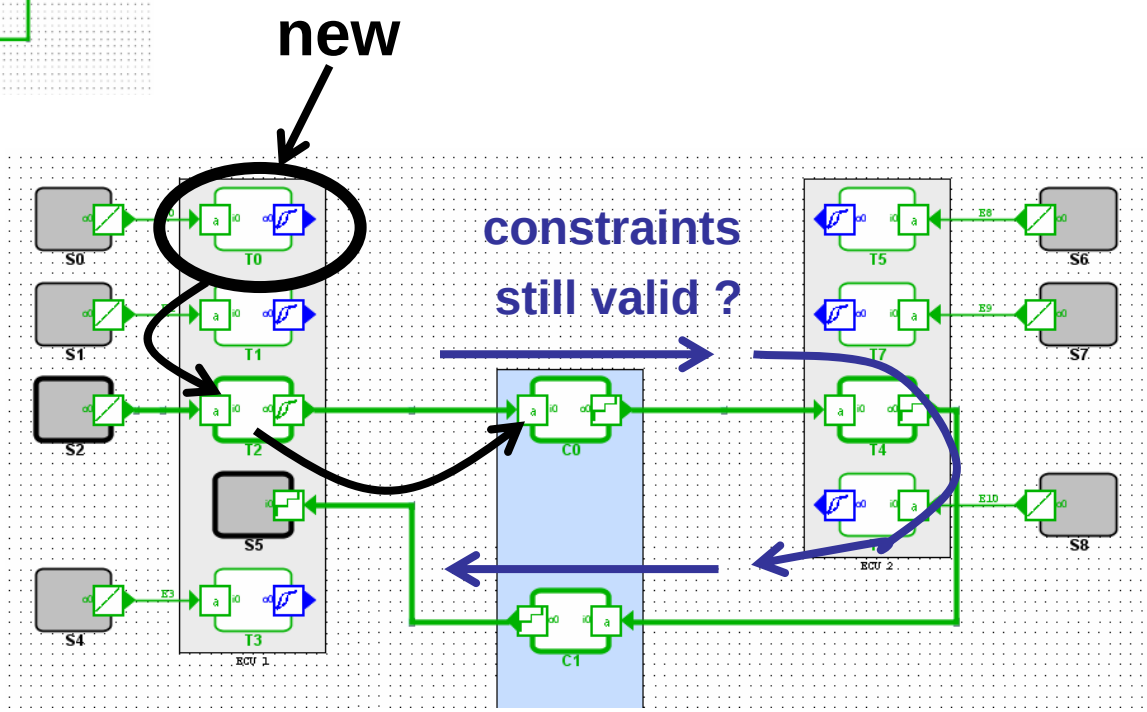
Bottom-up: Timing effects during integration

Key Message: Local Changes can have Global Effects !!!



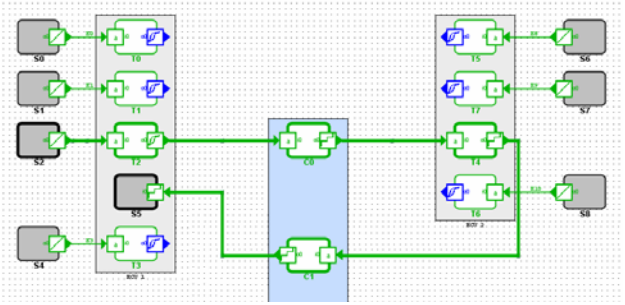
Example:
Task Timing Changed, e.g. Function Added

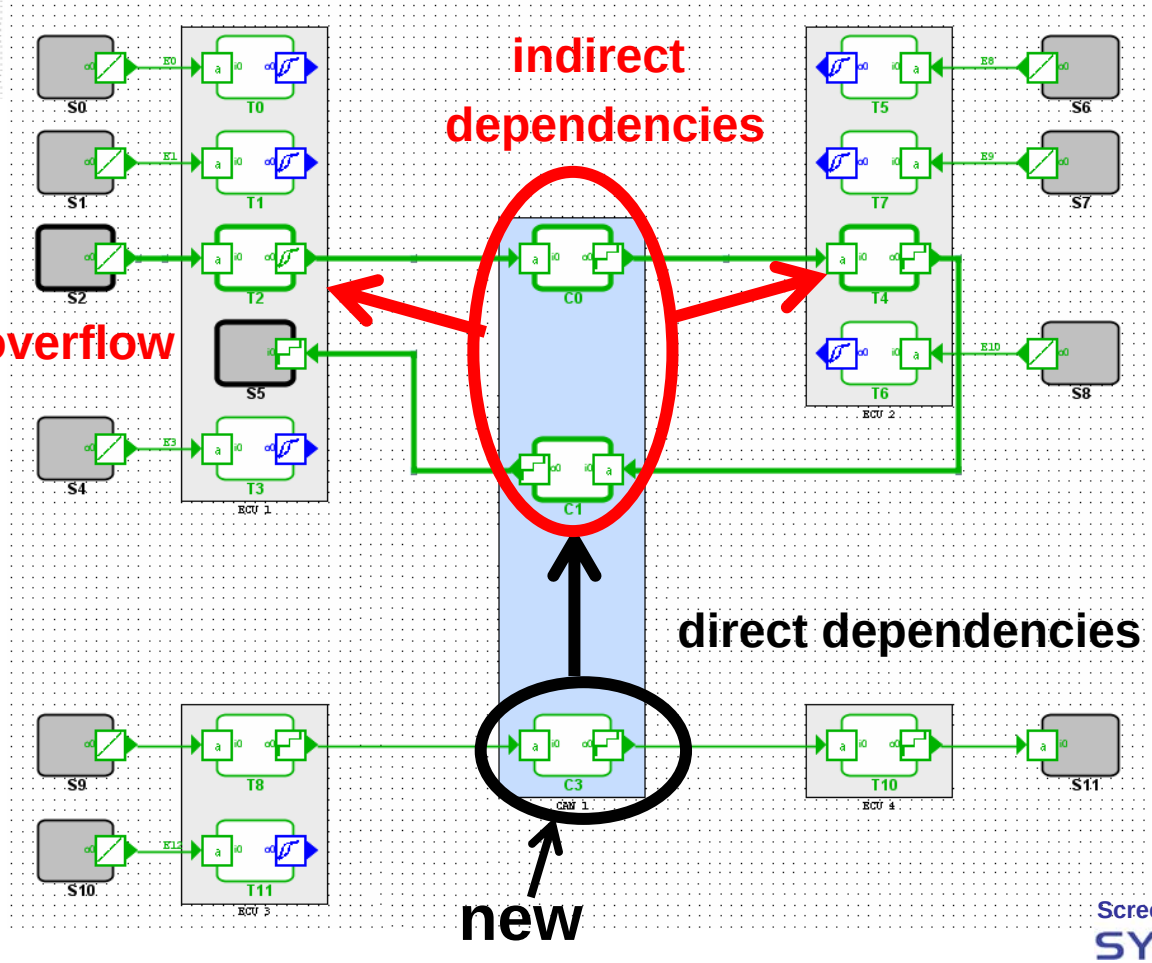




Screenshots by SYMTA

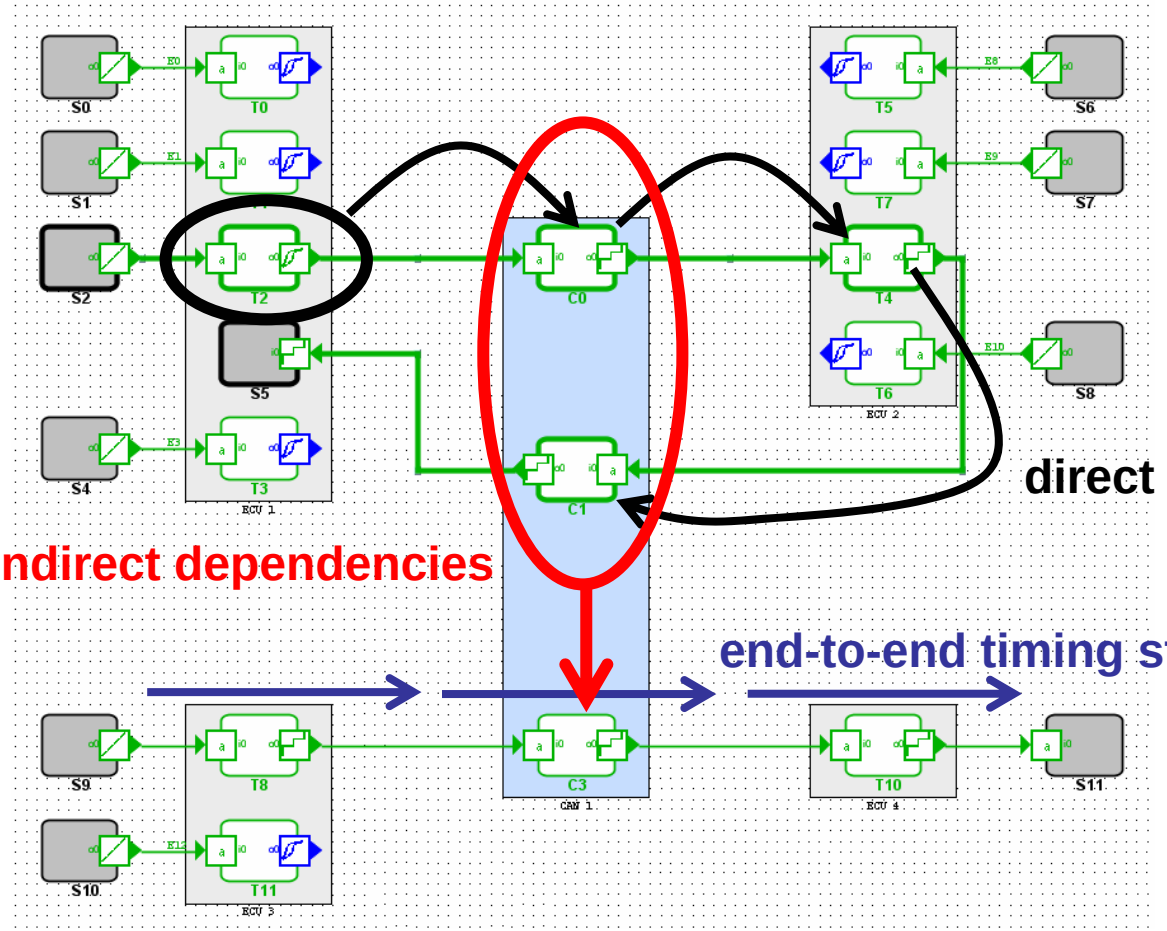
Example:
New Frame on Network





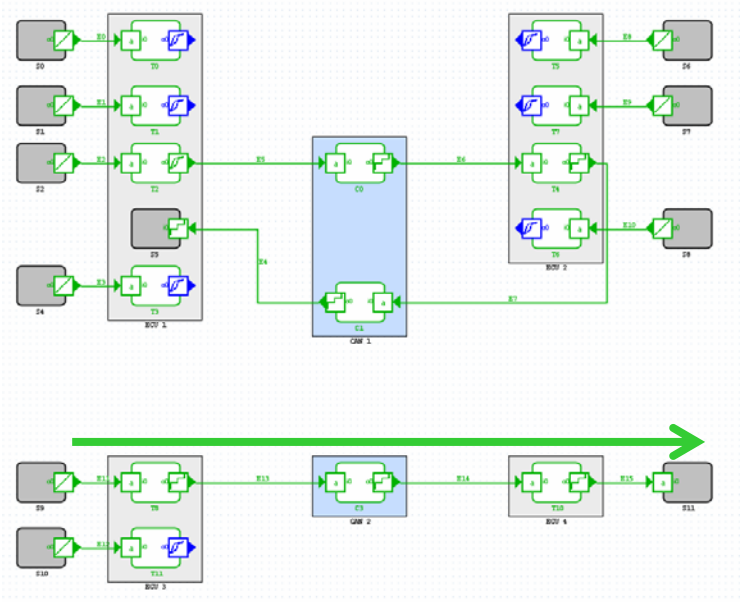
Screenshots by SYMTA

Example:
COM Layer Queuing Changed (FIFO -> priority)

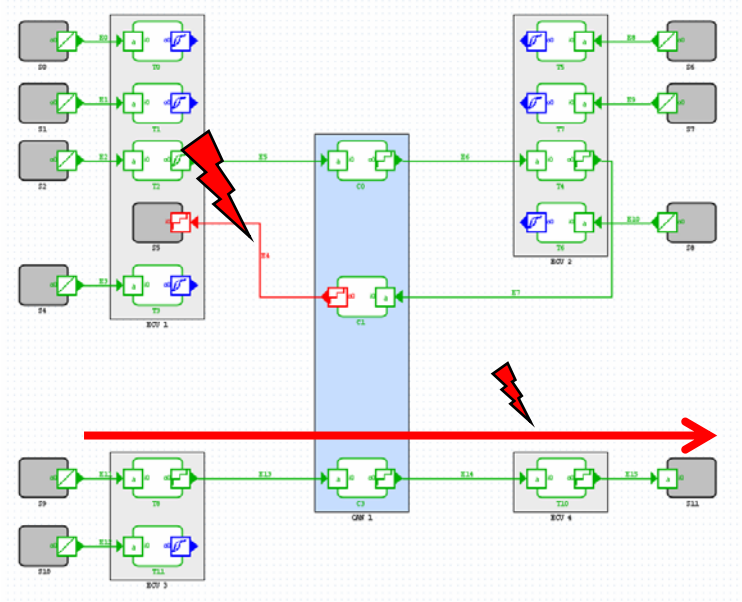


Screenshots by SYMTA

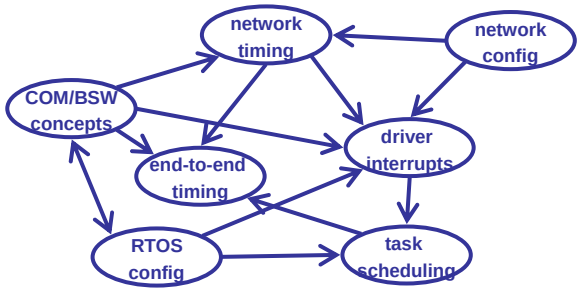
Use Case: System Integration (white box)



- two individual subsystems



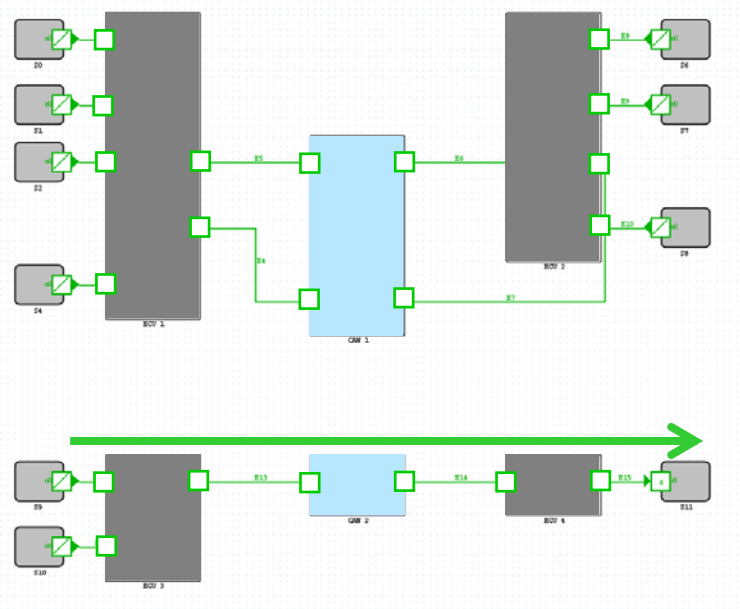
- integrated using shared bus

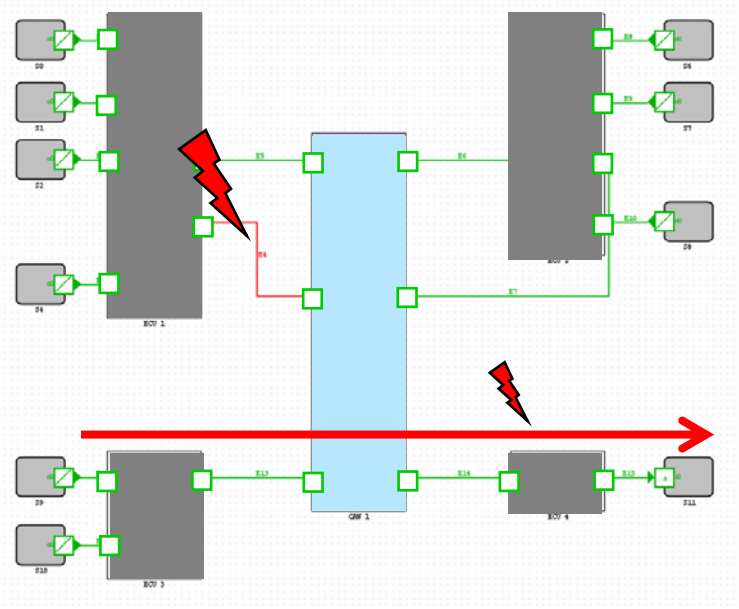


- **Question: How can this be analyzed & controlled ?**

Screenshots by SYMTA

Use Case: System Integration (black box)





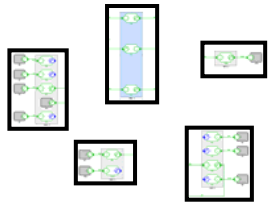
Even worse:

- **Only partial information available**
- **How to analyze this at all?**

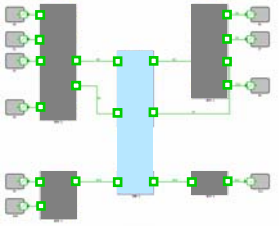
Screenshots by SYMTAS

Timing Analysis in Practice Today

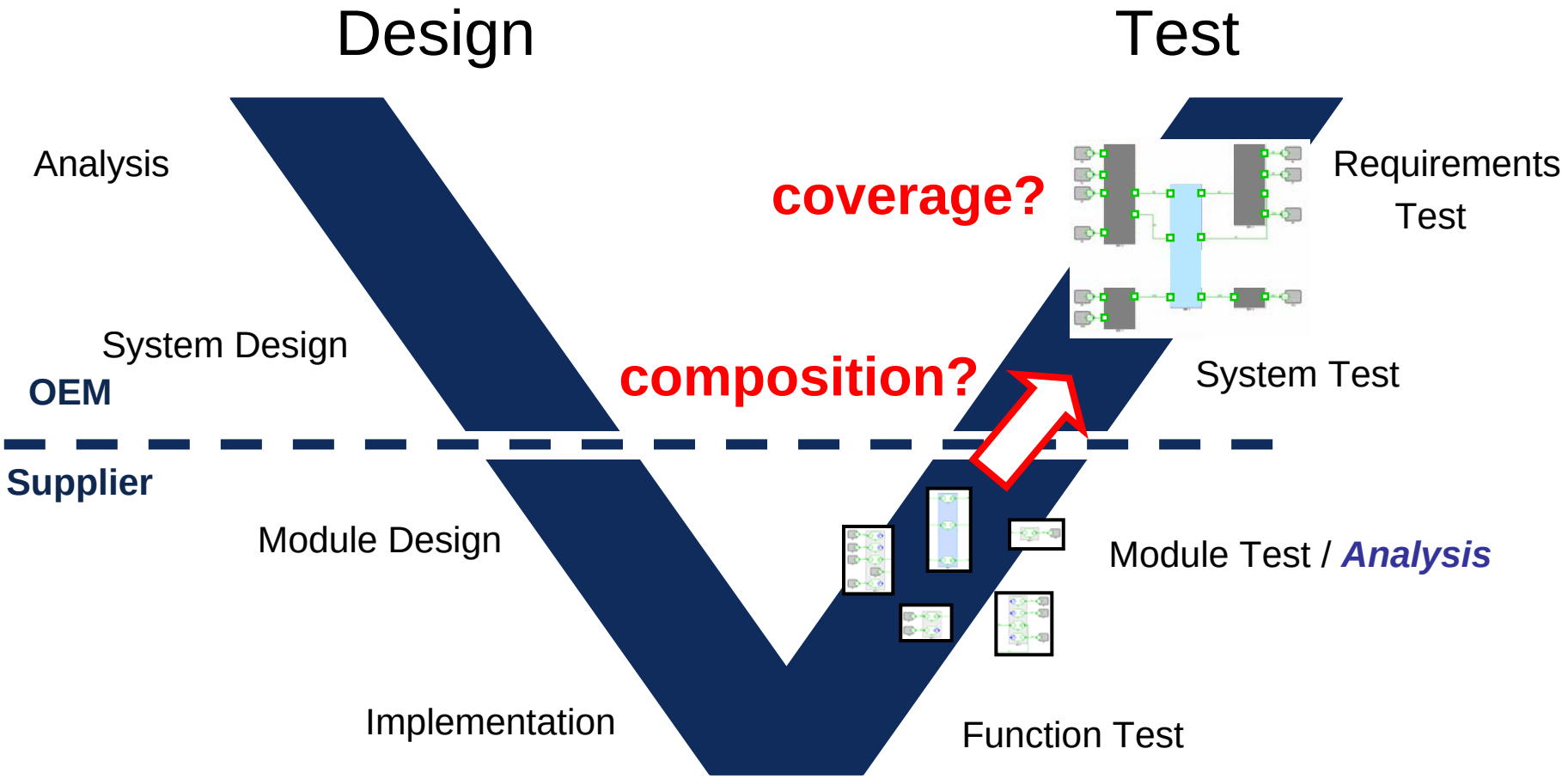
- Local analysis of individual components
  - good systematic approaches available
  - but mostly simplified "environment models"
  - ➔ later integration problems



- Testing of (sub-) systems after integration
  - whole environment available
  - but: unknown critical interactions prohibits corner case coverage
  - ➔ decreasing reliability

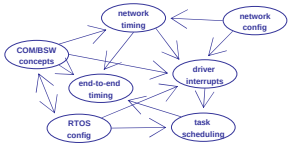


Established V-Model Design Process

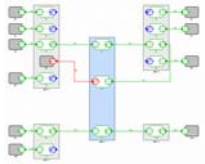


Summary: Bottom-Up System Integration

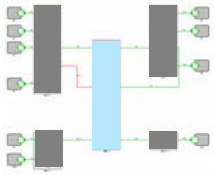
- Many local decisions have global effect, and are mutually dependent



- Technical Issue: System-level modeling of complex timing interaction



- Business Issue: Contracting & data availability along complex supply chains



- Current practice needs improvements

- **Key challenge for the AUTOSAR Timing Model!**

Overview

- AUTOSAR in general & target use cases
- Top-down: SW architecture vs. execution platform
- A closer look to key technical details
- Bottom-up: Integration & timing analysis practice
- **Implications w.r.t AUTOSAR goals**
- Conclusion

Review: AUTOSAR Goals

AUTOSAR shall be a vehicle for:

- Integration of SW-Cs from different SW suppliers
- Integration of ECUs from different tier-1 suppliers
- Platform design
  - re-use, extensibility, platform variants
  - portability and configurability at all levels

Approach:

- Standardized software architecture
- Modular and flexible function integration

Challenge: Timing Dependencies

- SW architecture does not reflect timing dependencies

- Timing is
  - mapping dependent (execution platform)
  - not as compositional/modular as the software architecure
  - complex
  - a fundamental technical issue
- Timing currently not thoroughly addressed by AUTOSAR
- **counters platform independent software & portability**

What is needed ?

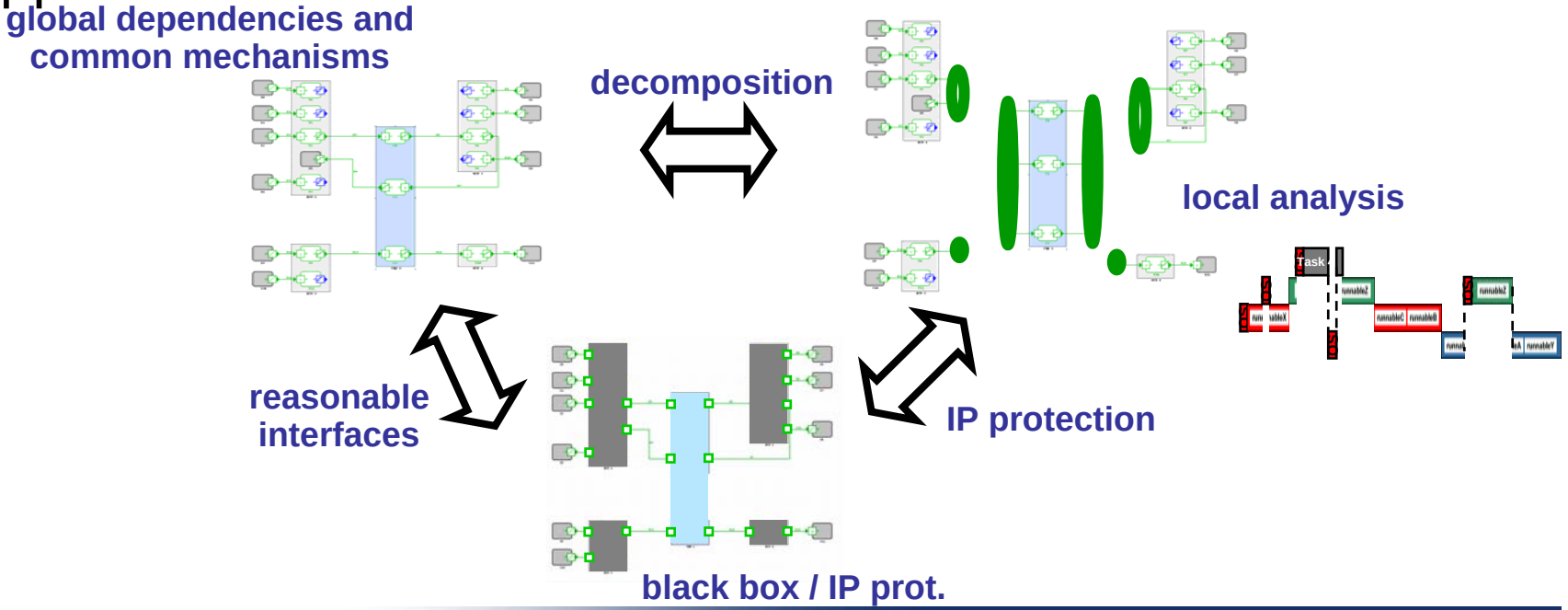
- Controlling timing dependencies requires reasonable specification models that are supported by analysis (tools)

"There is no point in modeling something that cannot be analyzed !!!" *(during some timing team meeting)*

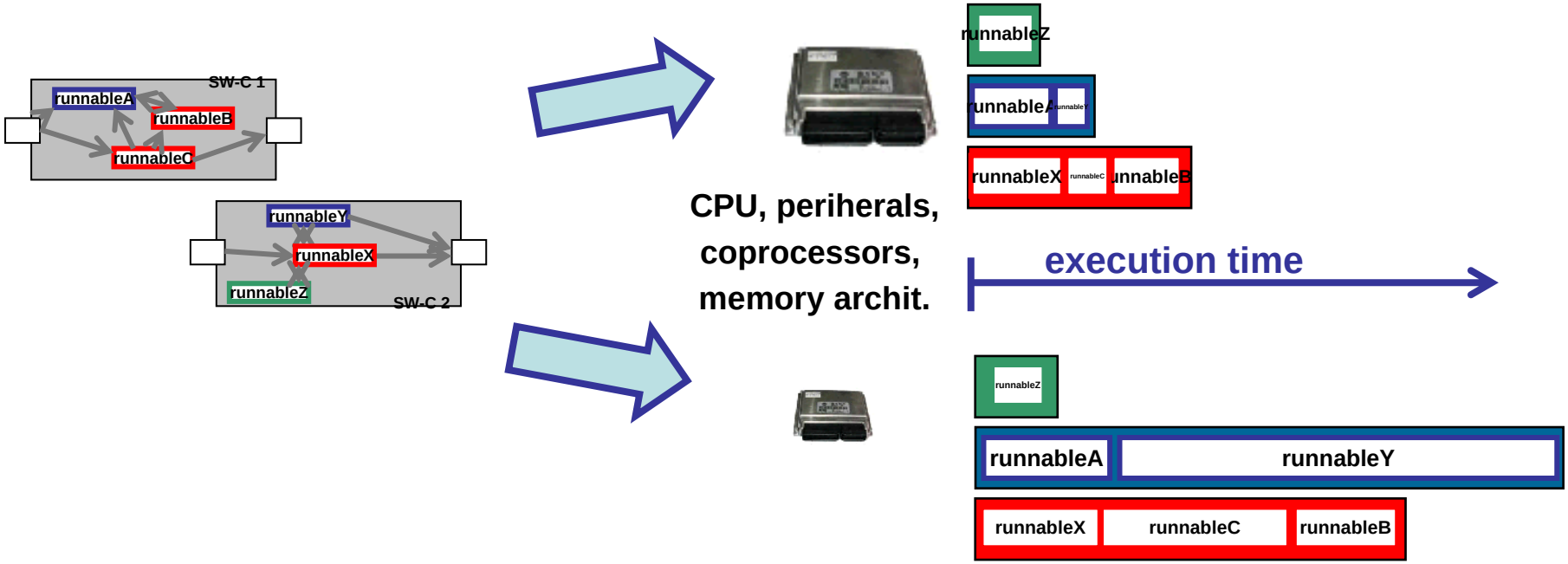
- Appropriate timing model ➔ technology
- Appropriate design "culture" ➔ business processes

How Could a Successful Timing Model Look Like?

- captures the complex dynamic timing dependencies, and the environment
- considers the used mechanisms (OS, protocols, BSW,...)
- enables de- / composition & local timing analysis
- allows black-box integration and IP protection
- applicable at different levels of detail



Software Suppliers can do: Timing Characterization



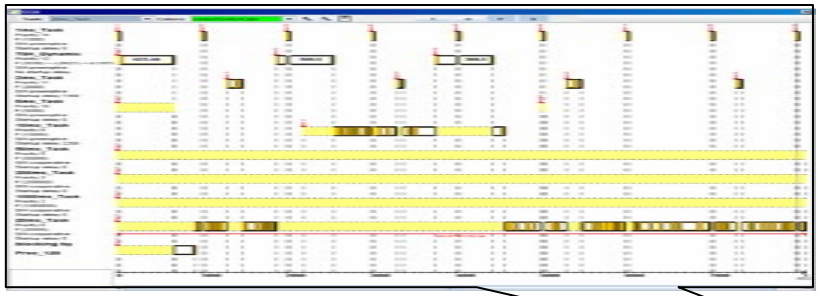
+ information about communication

(volume & access type)

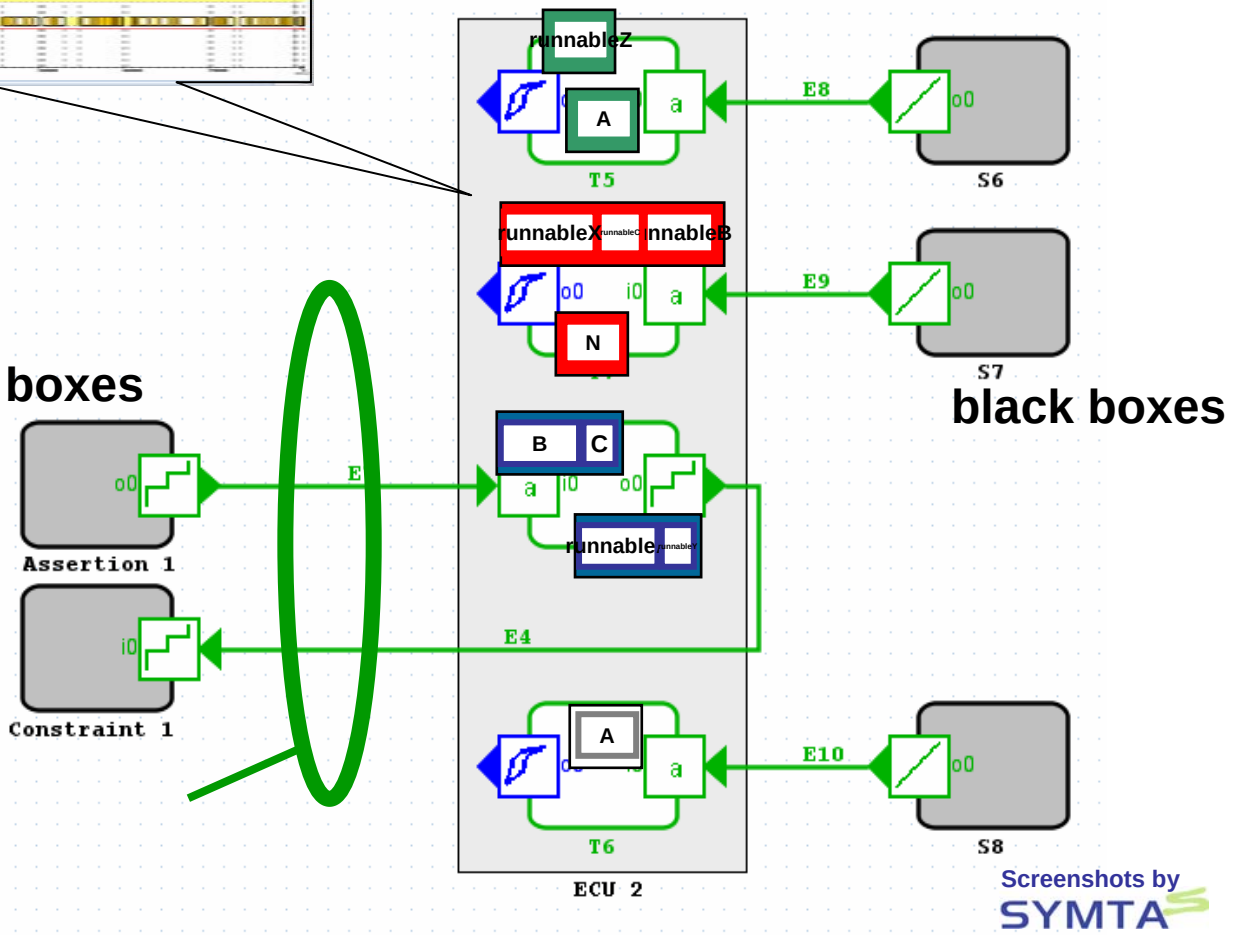
+ information about activation

events, interrupts, timers...

ECU Suppliers can do: Timing Analysis on ECUs



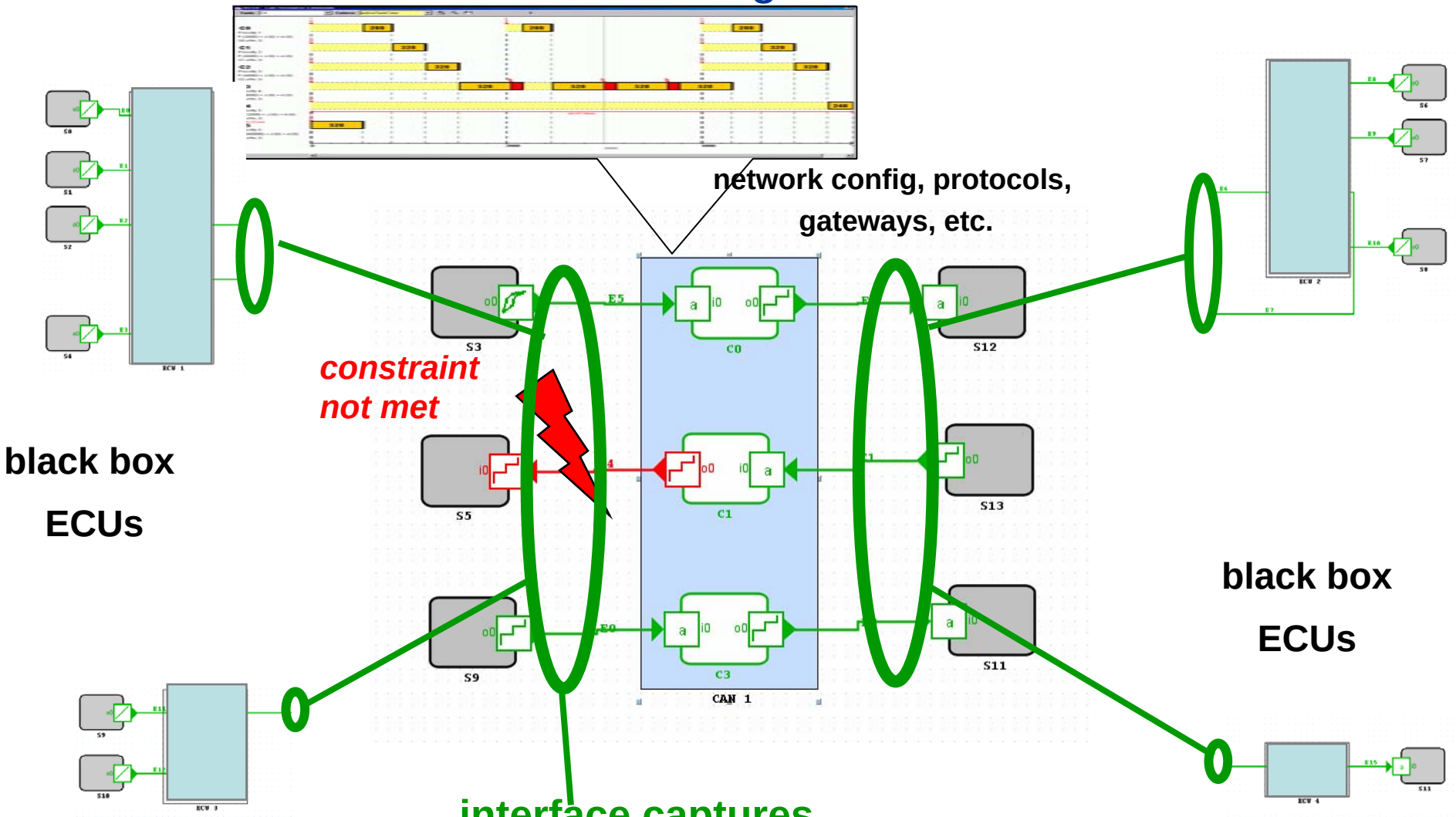
OS, scheduling, drivers, BSW, interrupts, timers



interface captures dynamic I/O behavior (jitter, min/max delays)

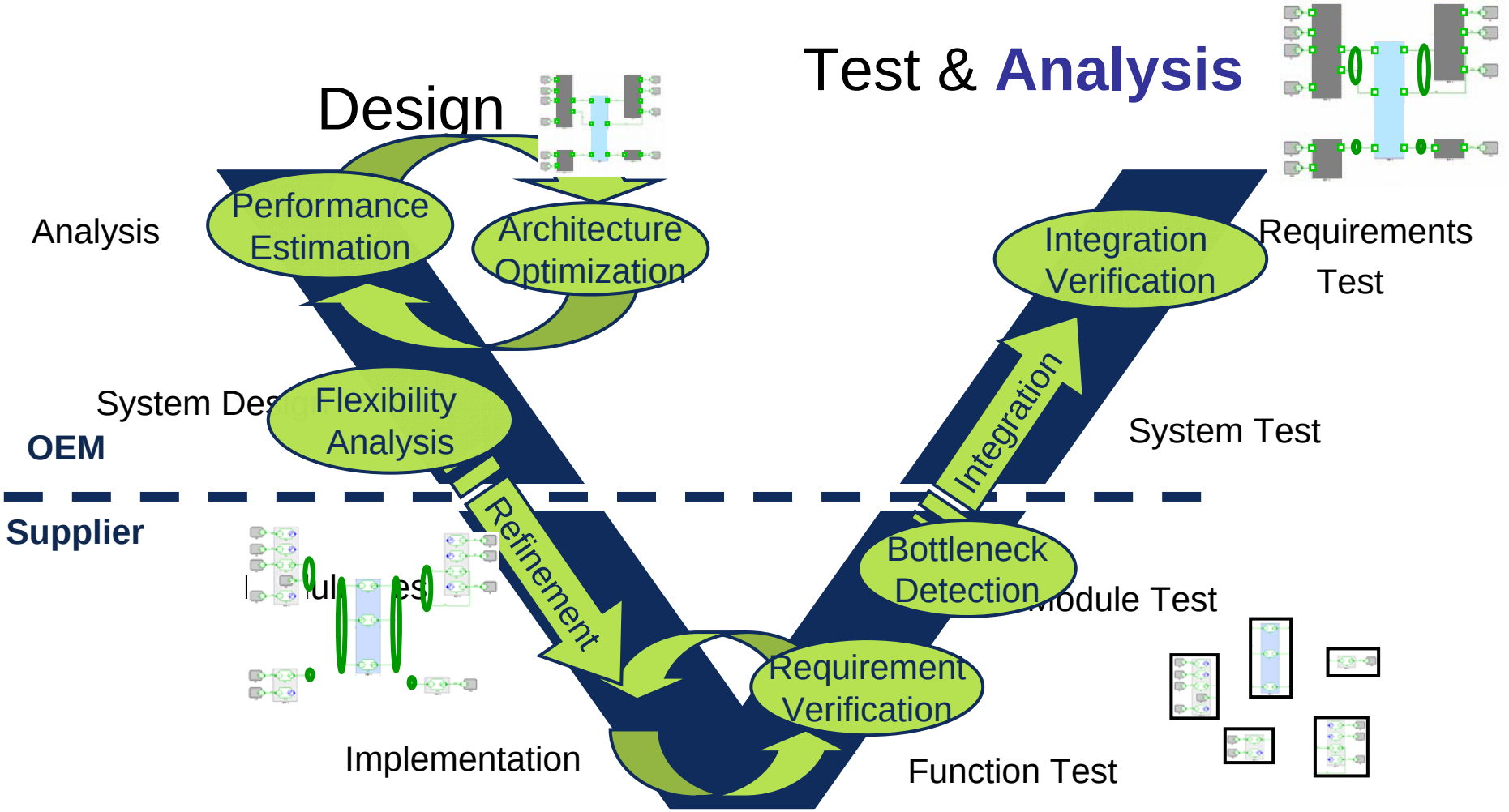
Screenshots by SYMTA

OEM can do: Control Timing on Bus/Network



Screenshots by SYMTA

Design Process Tomorrow ?



Cultural Issues

- Many approaches to timing modeling exist
- None has been chosen yet for AUTOSAR
- Why ???

Timing challenges require re-thinking of roles !!!

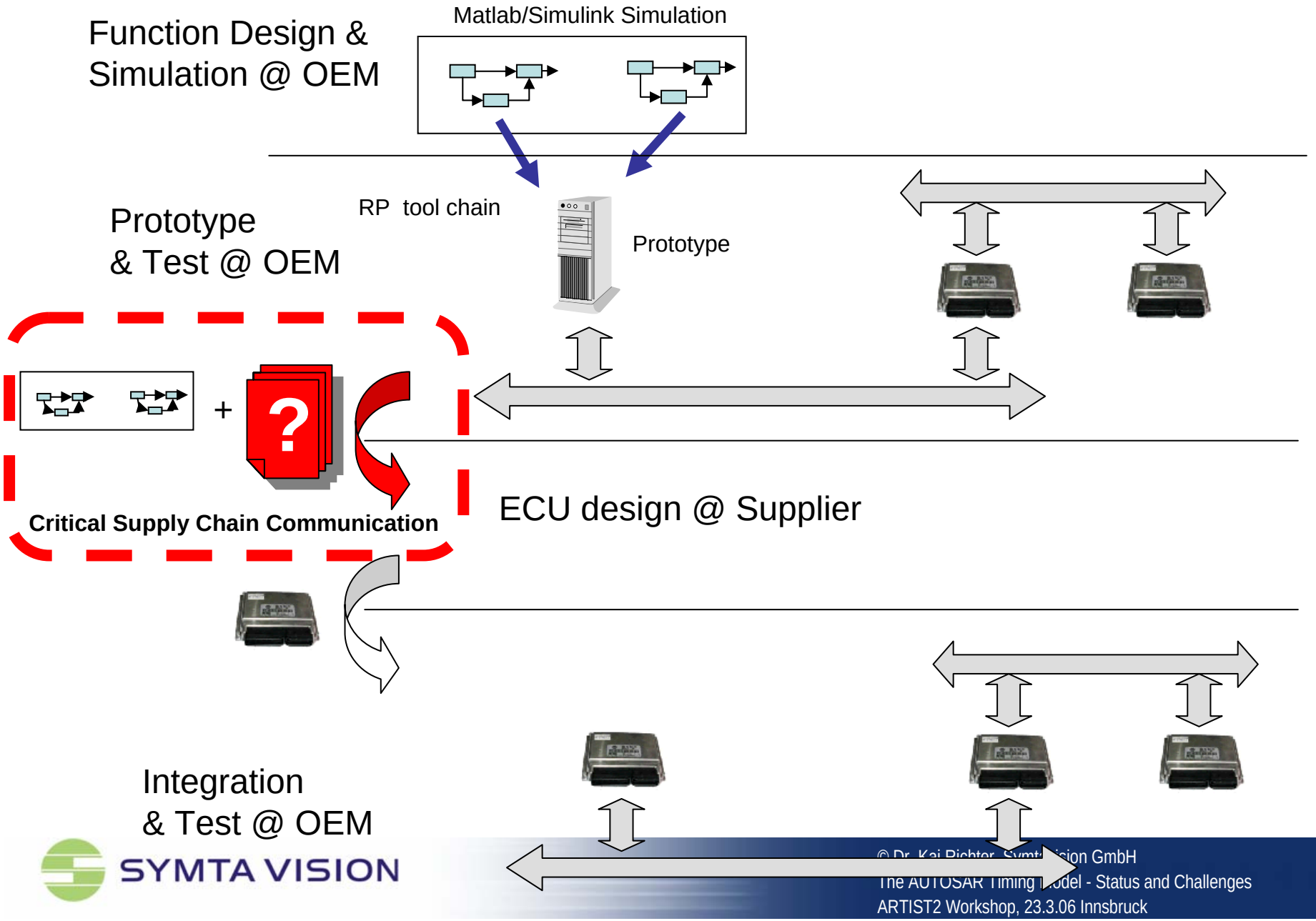
Suppliers Role

- Traditional role of Suppliers
  - function implementation
  - execution platform development
  - ..
- New to suppliers
  - responsible for ECU-network interactions
  - very detailed requirements / constraints
  - traceable verification, clear responsibility / liability
  - disclosure of information relevant for timing
  - more competition due to comparability

OEMs Role

- Traditional role of OEMs in E/E design
  - function design (Matlab, etc..)
  - prototyping
  - taking suppliers liable for correct functioning
- New to OEMs
  - network timing effects out of supplier responsibility
  - timing is a technical problem requiring a technical solution (no management solution)
  - consideration of SW architecture and execution platforms
  - dealing with systematic timing and QoS contracts
- OEM needs to reason about integration much earlier
  - Quality can not be added at the end of "cooking" (like salt) !

Supplier-OEM Communication Scenario



New OEM Responsibilities and Possibilities

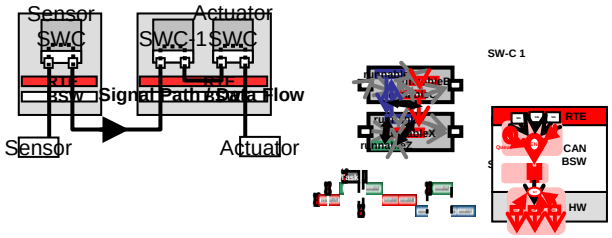
- Facing timing as a technical challenge, OEMs can
  - understanding network timing ➔ **more systematic dimensioning, configuration, optimization**
  - focusing on the interaction of ECUs with the network ➔ more systematic timing constraints for suppliers (timing chains and HOPs) ➔ **increasing integration reliability / reduced risk**
  - better understanding of COM-layer effects ➔ systematic implementation constraints for suppliers (OEMs defines a "standard BSW core") ➔ **guaranteed compliance of supplied ECUs with OEMs network**

Research Bodies Role

- Traditionally
  - develop solution approaches for technical problems
  - are used to industry requesting their help
  - develop foundations for EDA tools
- AUTOSAR:
  - an entire community with an obvious problem ...
  - ... long time not asking for direct assistance
- Why is that?

Industry-Research Mismatch ???

Automotive Industry

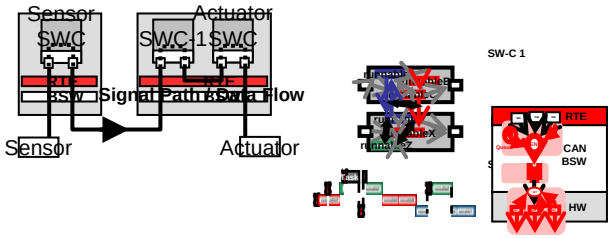


complex systems,
manifold dependencies

revolutionary problems

Industry-Research Mismatch ???

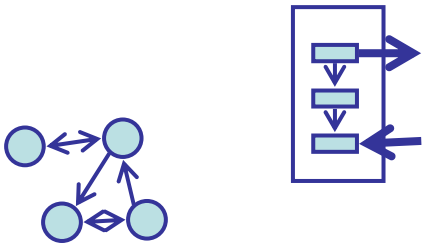
Automotive Industry



complex systems,
manifold dependencies

revolutionary problems

Research Community



clear semantics,
well-defined interactions

revolutionary solutions

Conclusion

- Timing is "quite new" to automotive industry (esp. OEMs)
- SW architecture view not sufficient to capture timing
- Must take into account the execution platform systematically, is complex
- Needs formal models -> EDA Tools -> confident users
- Allows engineers to reason about alternatives
- Need to come:
  - SW engineering view enhancements
  - better (more systematic) platform mechanisms / basic software
  - more flexible design rules
  - revised “way of thinking” (especially for OEMs)