Component-based Design

EU-US Workshop

on Future Challenges in Embedded Systems Design

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Component-based engineering - Motivation

Building complex systems from simpler ones is universally the basis for any system theory and practice.

• Raises hard problems about concepts, languages and their semantics e.g. What is an architecture? What is a scheduler? How synchronous and asynchronous systems are related?

• Requires a deep understanding of basic system design issues such as development methodologies (combination of techniques and tools, refinement) and design principles

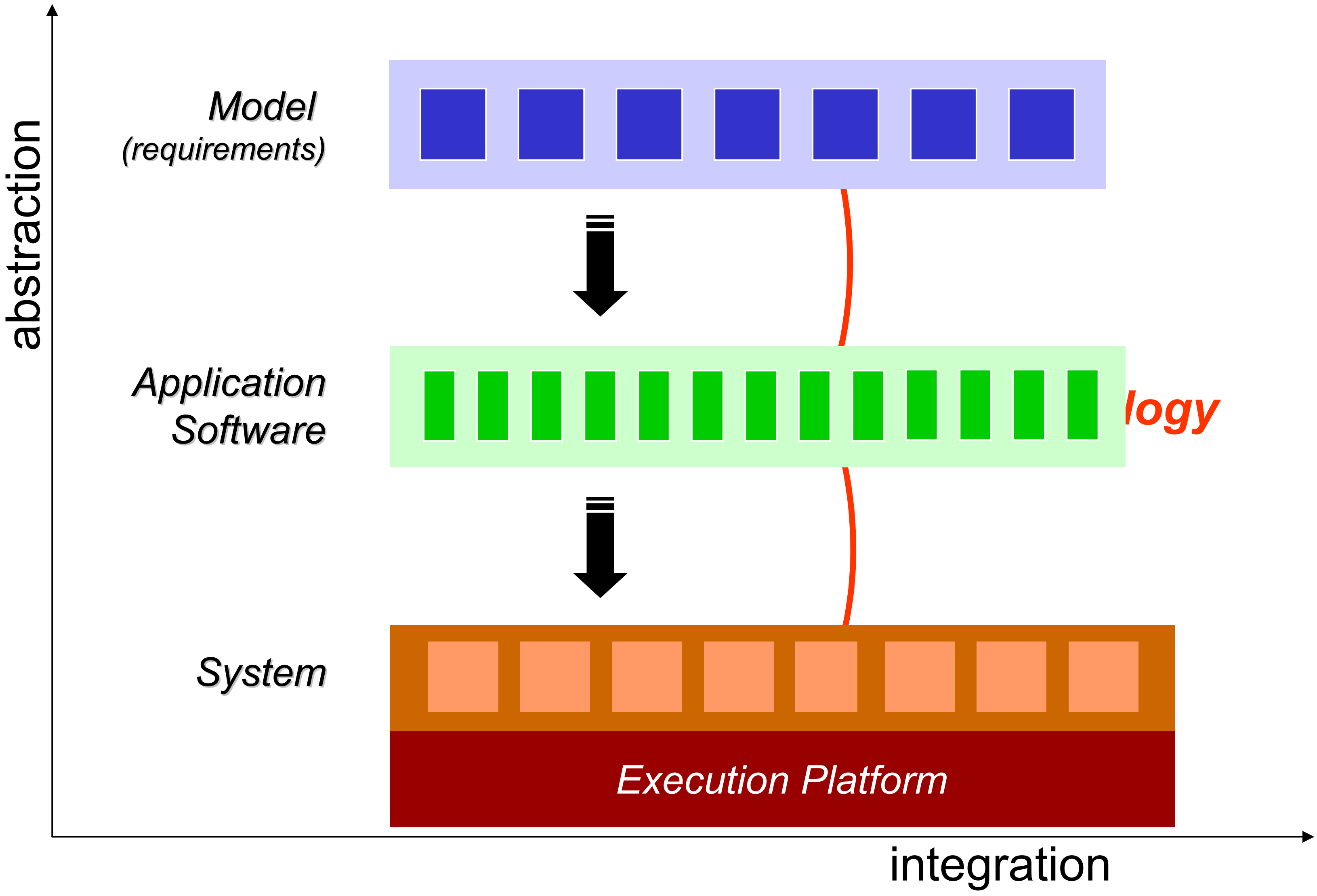
It's not just playing with syntax and graphical tools ….

Component-based engineering - Related stuff

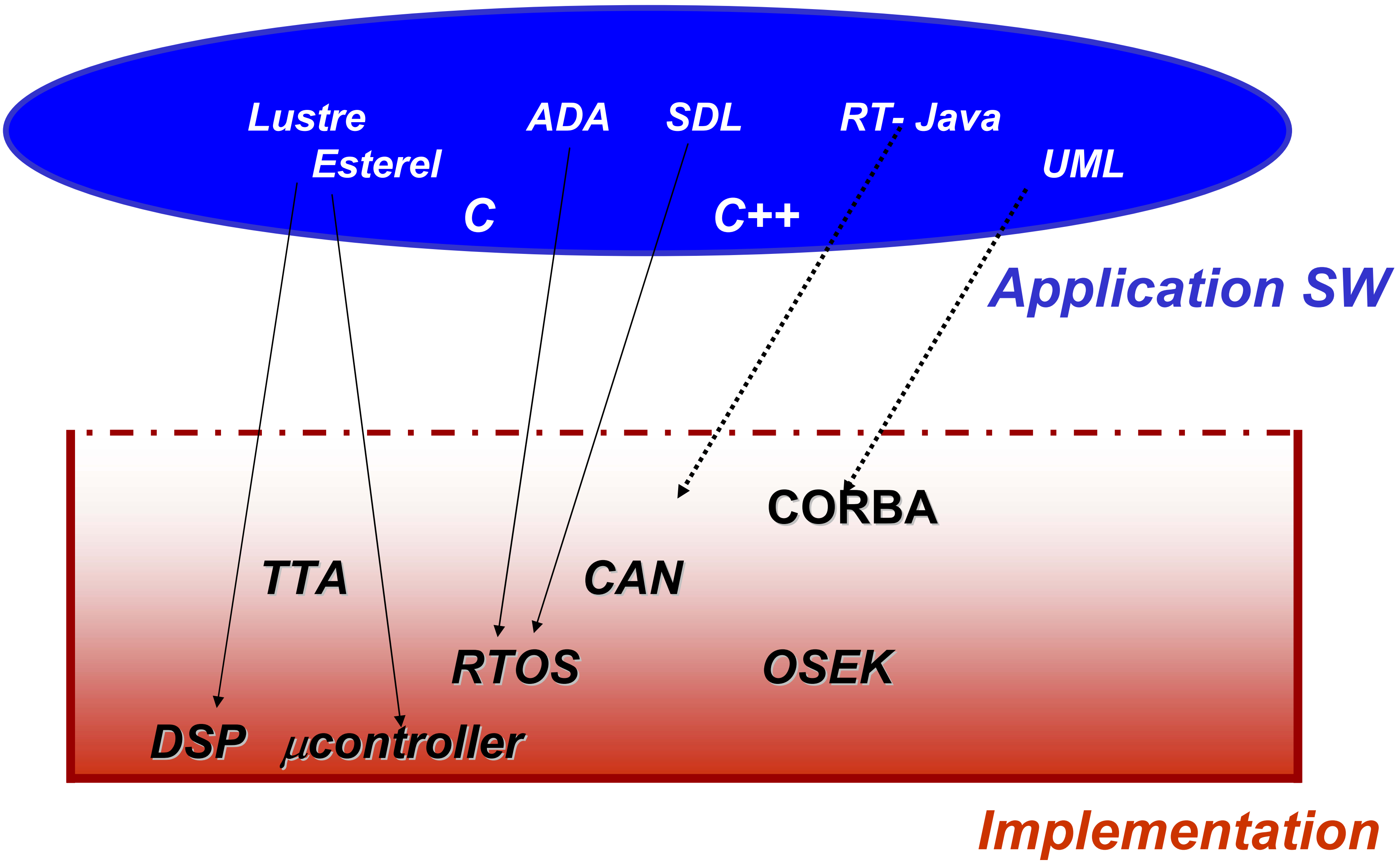
The following deal with issues related to component-based engineering:

- Architecture Description Languages focusing on non-functional aspects or SW Design Description Languages
- Modeling languages: Statecharts, UML, Simulink/Stateflow, Synchronous languages, SystemC, Metropolis, Ptolemy
- Coordination languages (extensions of programming languages): Linda, Javaspaces, TSpaces, Concurrent Fortran, …
- Middleware standards: IDL, Corba, Javabeans, .NET
- Software development environments: PCTE, SWbuses, Softbench, Eclipse
- Process algebras and automata : Pi-Calculus, I/O automata

System Design – Abstraction Levels



System Design: From application SW to implementations



System Design: From application SW to implementations

Logical abstract time

High level structuring constructs and primitives

Simplifying synchrony assumptions wrt environment

Application SW

Physical, Non functional properties

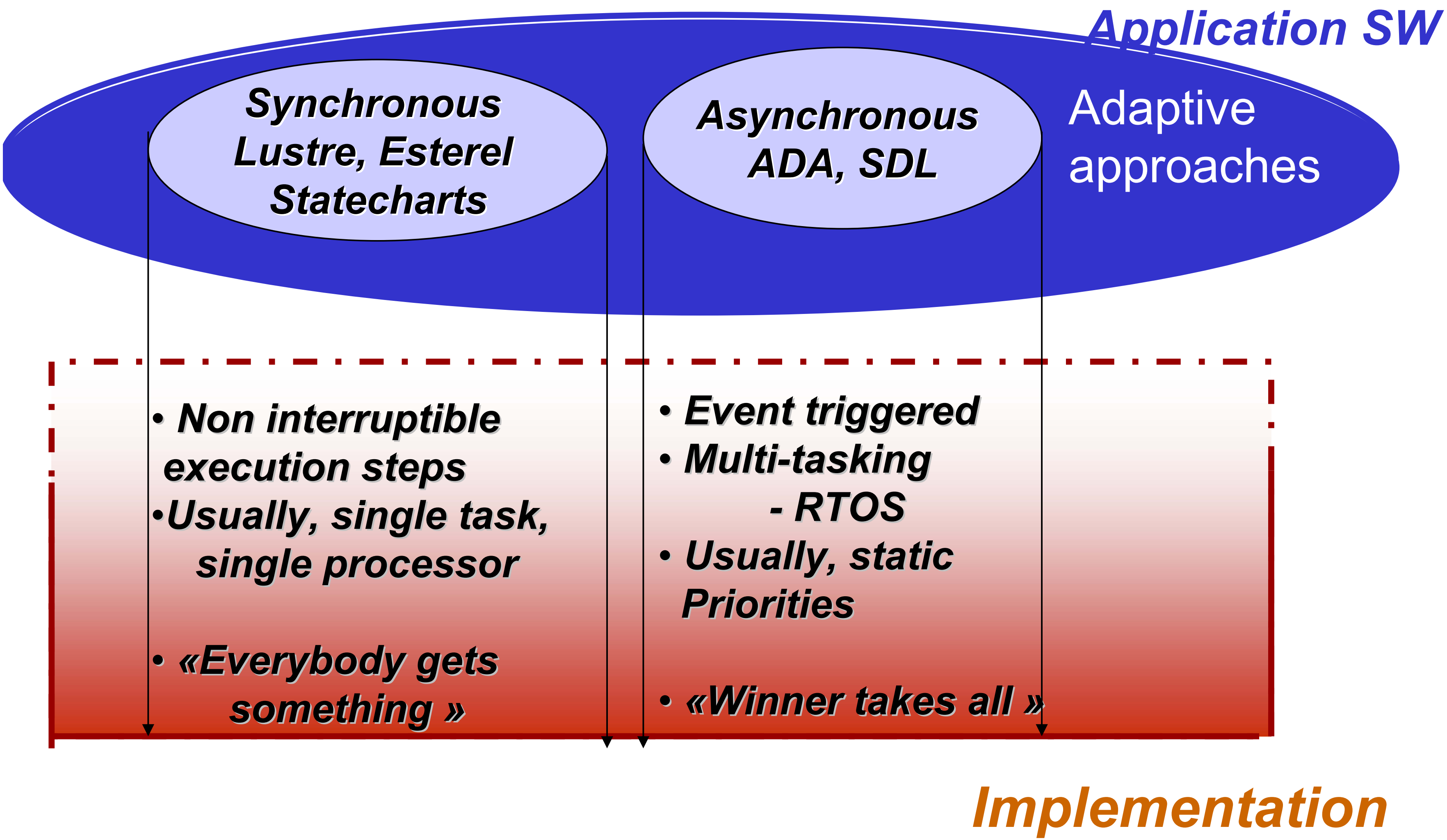
Execution times, interaction delays, latency

Task coordination, resource management, scheduling

Implementation

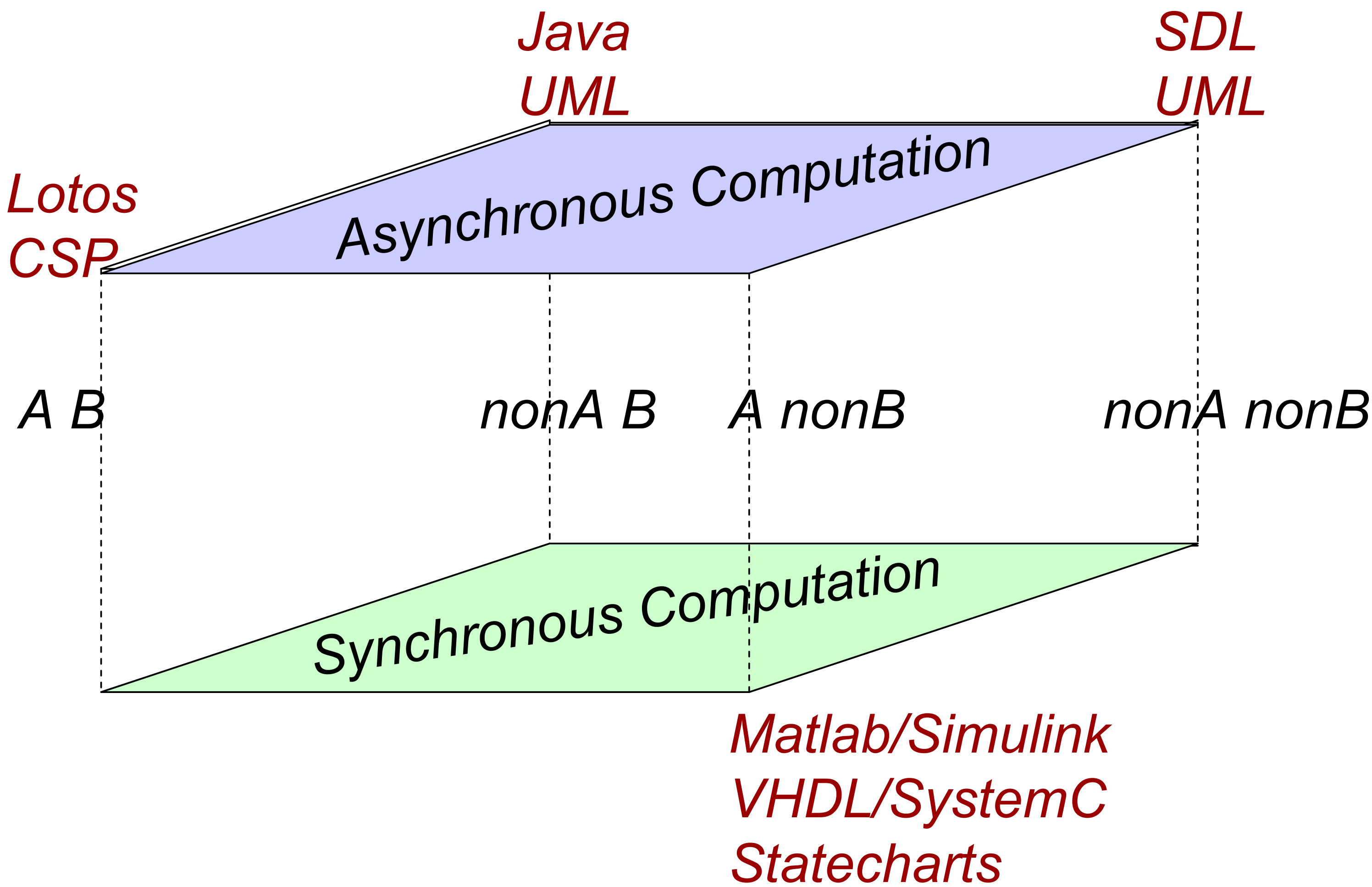
System Design: From Application SW to Implementations

synchronous vs. asynchronous



Heterogeneity

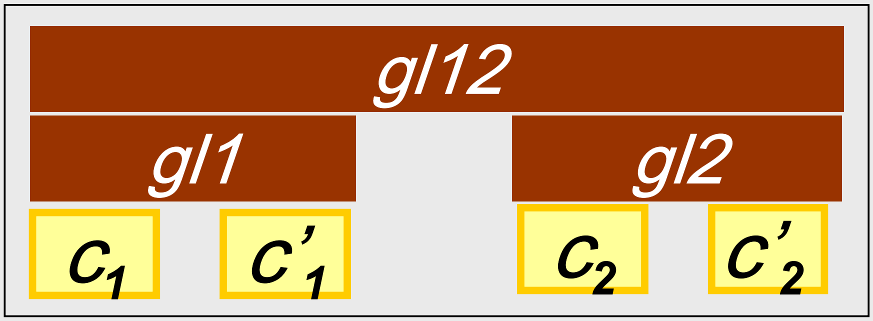
A: Atomic interaction *B: Blocking interaction*



Component-based design

Build a component C meeting a given property P from

- C_0 a set of atomic components
- GL a set of operators on components

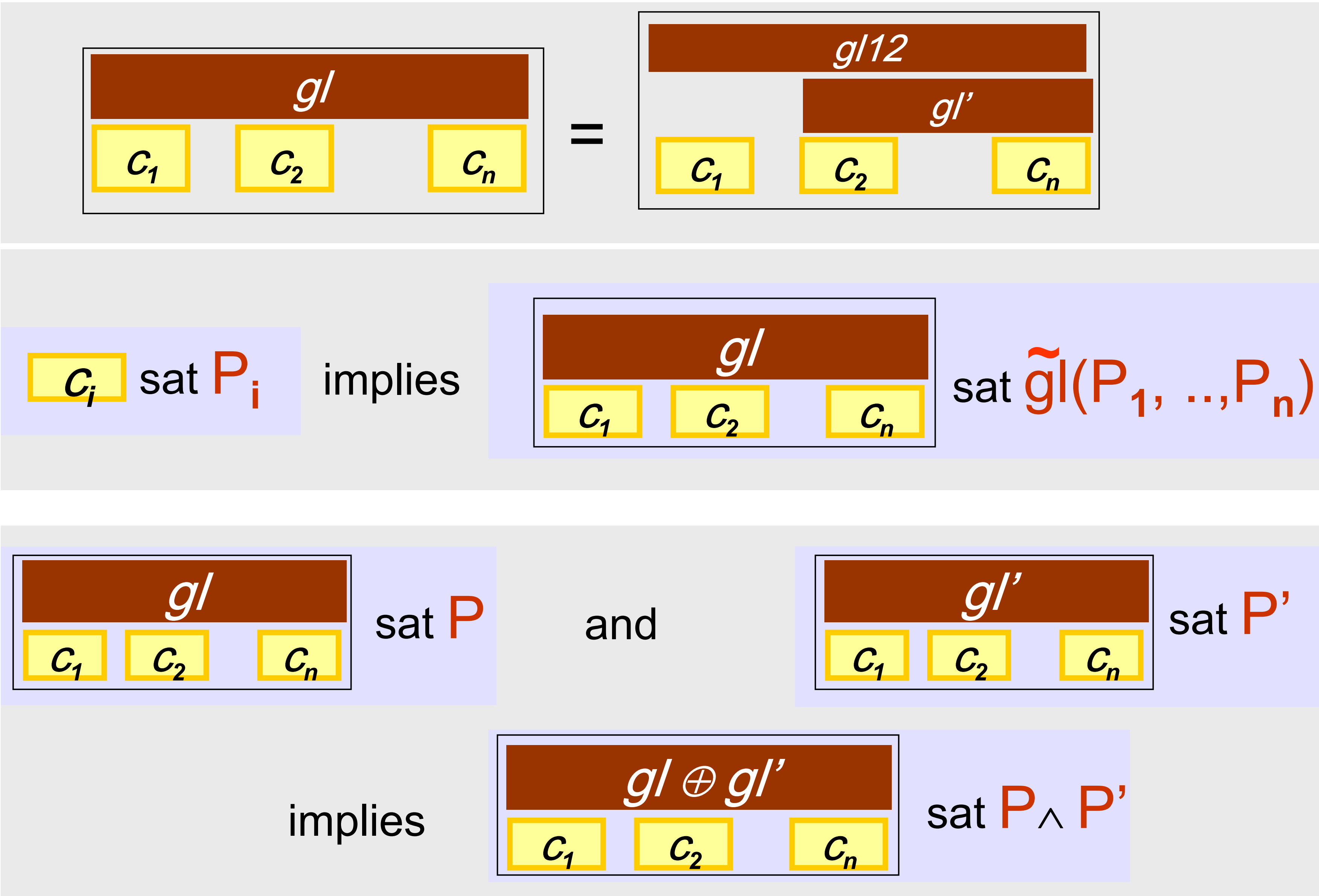


sat P

Glue can be any mechanism used for communication and control such as protocols, controllers, HW architectures.

Problem: Find a «minimal» set of operators with rules for component-based construction

Component-based design – Requirements



Architectures

Provide a rigorous and general basis for architecture modeling, design and implementation encompassing

- A general concept of architecture as a means to organize computation (behavior, interaction, control)
- Heterogeneity and specific styles and paradigms, e.g.
    - synchronous and asynchronous execution
    - heterogeneous interaction (strong, weak, event-driven, state-driven)
    - architecture styles e.g., client-server, blackboard architecture
- Correctness-by-construction results for generic properties such as deadlock-freedom, liveness, safety.
- Automated support for component integration and generation of glue code meeting given requirements

Adaptive Systems

- Adaptivity is the capacity of a system to meet given requirements including safety, security, and performance, in the presence of uncertainty in its external or execution environment.

It is a means for enforcing predictability in the presence of uncertainty

- Uncertainty is characterised as the difference between average and worst-case behavior of a system's environment. The trend is towards drastically increasing uncertainty, due to:
  - Connectivity with complex, non-deterministic, possibly hostile external environments
  - Execution platforms with sophisticated HW/SW architectures (layering, caches, speculative execution, …)

Adaptive systems

- The increase in uncertainty gives rise to 2 diverging approaches and technologies:
  - **Critical systems engineering** based on worst-case analysis and static resource reservation e.g. hard real-time approaches, massive redundancy.
  - **Best effort engineering** based on average case analysis e.g., soft real-time for optimization of speed, memory, bandwidth, power,
- This leads to a physical separation between critical and non critical parts of a system running on dedicated physical units, which implies increasing costs and reduced hardware reliability, e.g.: an increasing numbers of ECUs in automotive systems.

- *It is essential to develop holistic adaptive design techniques combining the advantages of the two approaches: guaranteed satisfaction of critical properties and efficiency by making best possible use of available resources (processor, memory, power).*

Adaptive systems