UML MARTE

www.omgmarte.org

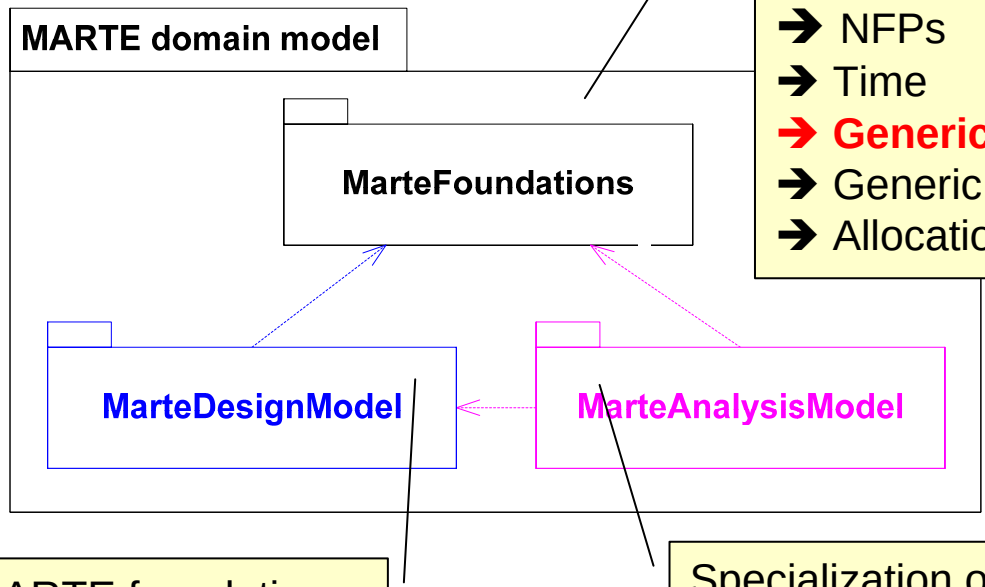
MARTE Tutorial:

Resources Modeling

Sébastien Gérard (CEA LIST)
sebastien.gerard@cea.fr

cea list THALES INRIA

MARTE Overview



Foundations for RT/E systems modeling and analysis:
- ➔ CoreElements
- ➔ NFPs
- ➔ Time
- ➔ **Generic resource modeling**
- ➔ Generic component modeling
- ➔ Allocation

Specialization of MARTE foundations for modeling purpose (specification, design, …):
- ➔ RTE model of computation and communication
- ➔ **Software resource modeling**
- ➔ **Hardware resource modeling**

Specialization of foundations for annotating model for analysis purpose:
- ➔ Generic quantitative analysis
- ➔ Schedulability analysis
- ➔ Performance analysis

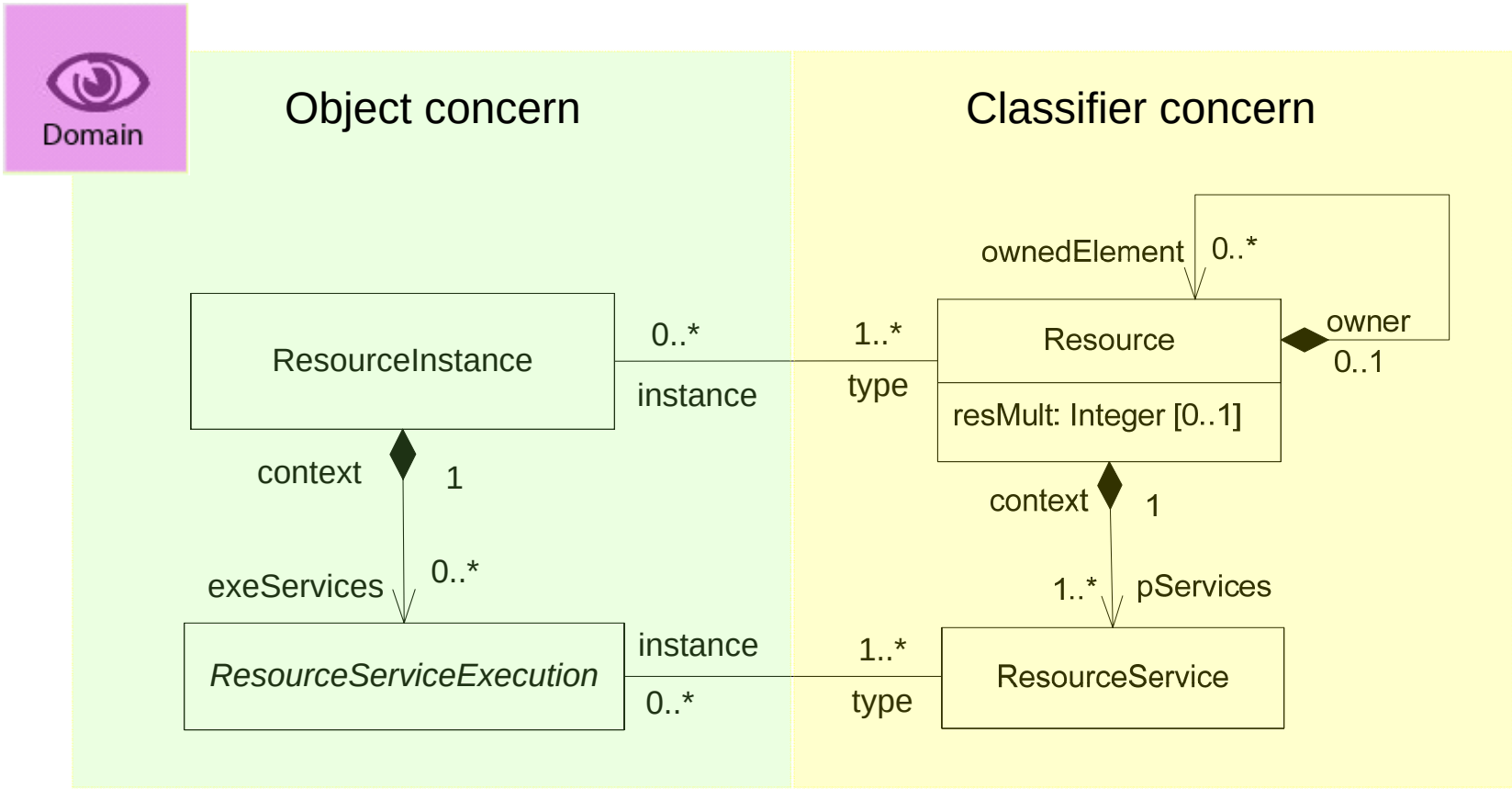
Extracted from S.Gerard (ECRTS07)

Outlines of the GRM package

- **Provides basic concepts for modeling a general (high-level) platform for processing RTE applications**

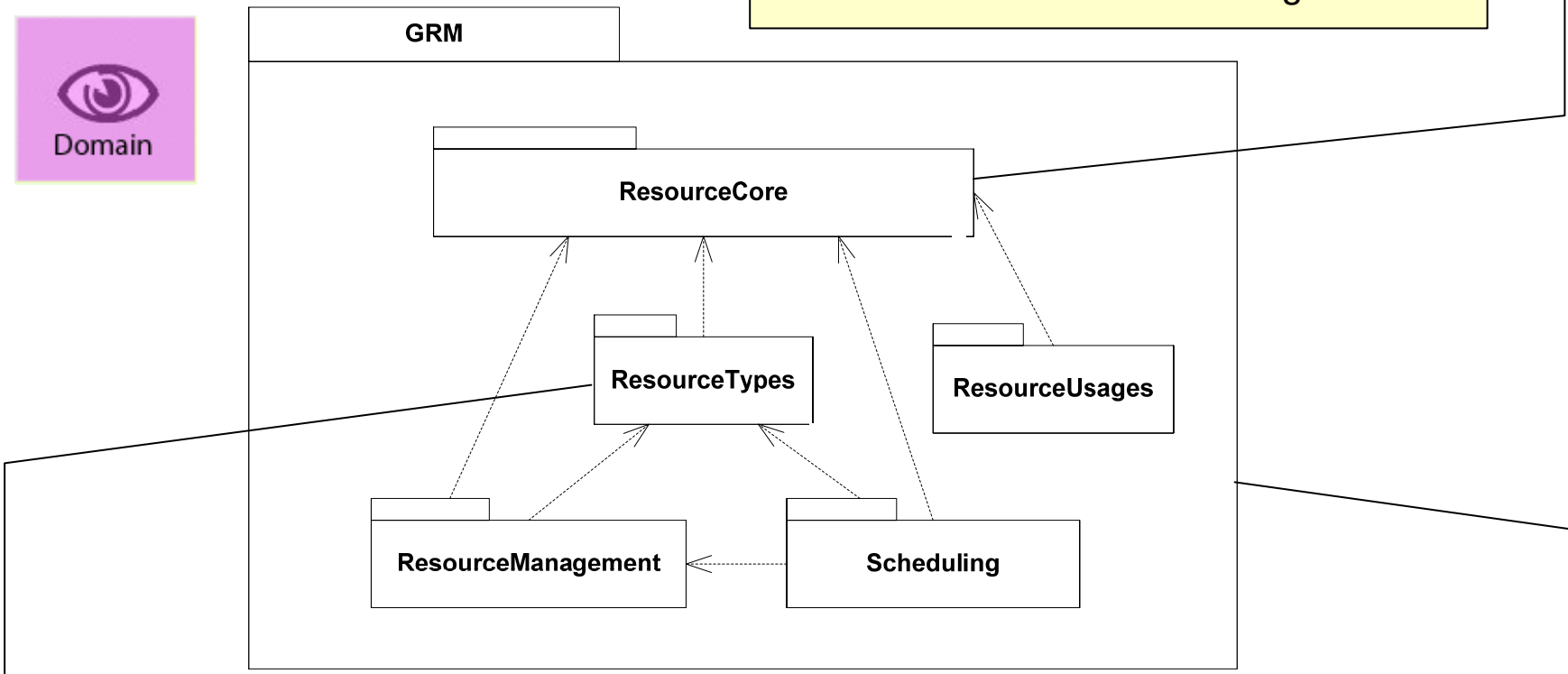
- **Build in a bottom-up process to abstract finer-level platforms**
  - Processing platform for design concern
    - See HRM and SRM
  - Processing platform for analysis concern
    - See GQAM-related ptf and further refinements for performance and schedulability analysis

Essence of the GRM Package



Generic Resource Modeling

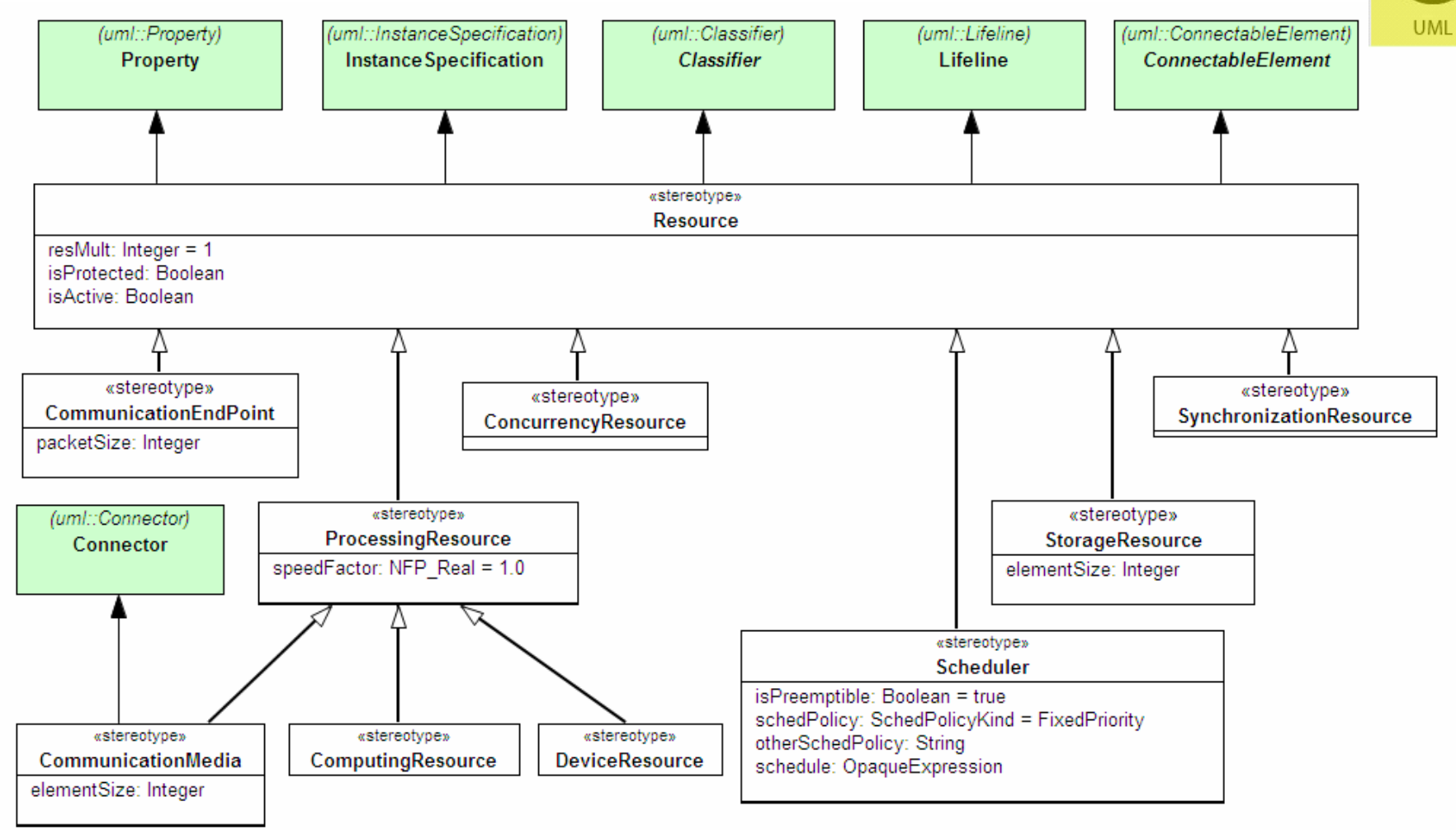
Resource offers Services and may have NFPs for its definition and usage



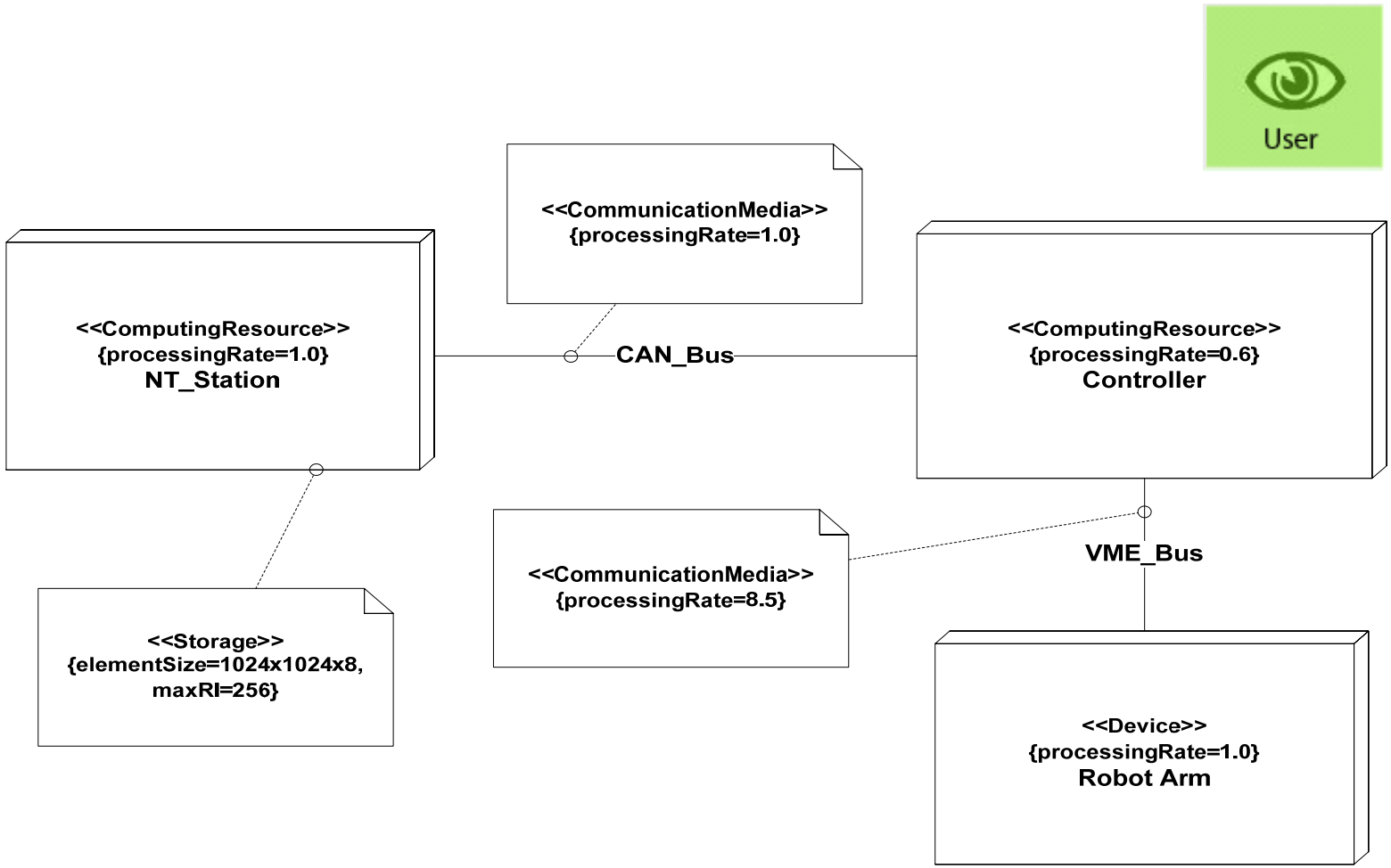
A rich categorization is provided: Storage, Synchronization, Concurrency, Communication, Timing, Computing, and Device Resources may be defined.

Shared resources, scheduling strategies and specific usages of resources (like memory consumption, computing time and energy) may be annotated.

Extract of the MARTE sub-profile for GRM



Generic resource modeling example



Allocation & Refinement

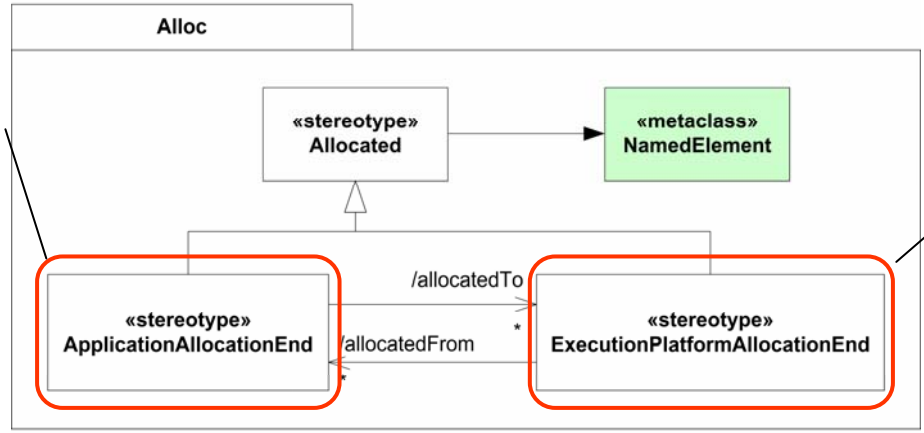
- **Basic ideas**
  - Allocate an application element to an processing platform element
  - Refine a general element into one or several more specific elements

- **Inspired by the SysML allocation**
  - Can only allocate application to execution platform
  - Can attach NFP constraints to the allocation

A two step process for allocation modeling

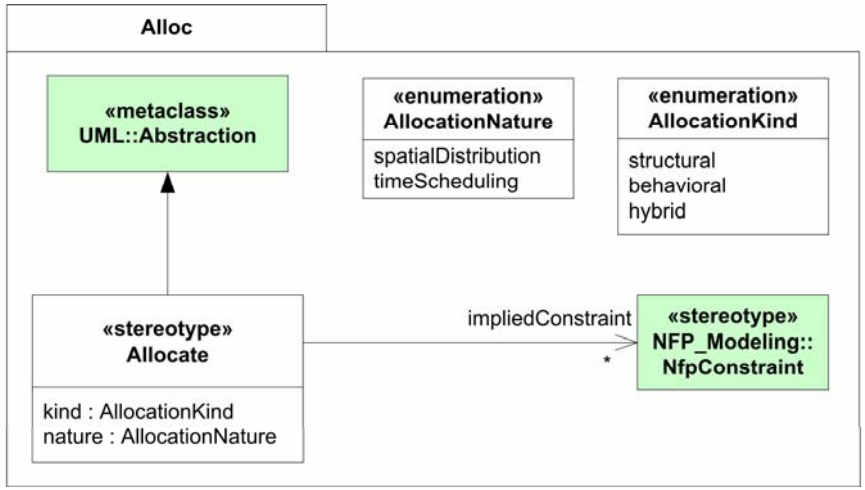
- **Identify possible sources and targets of allocations**

What can be allocated, the logical view:
➔ structure or behavior

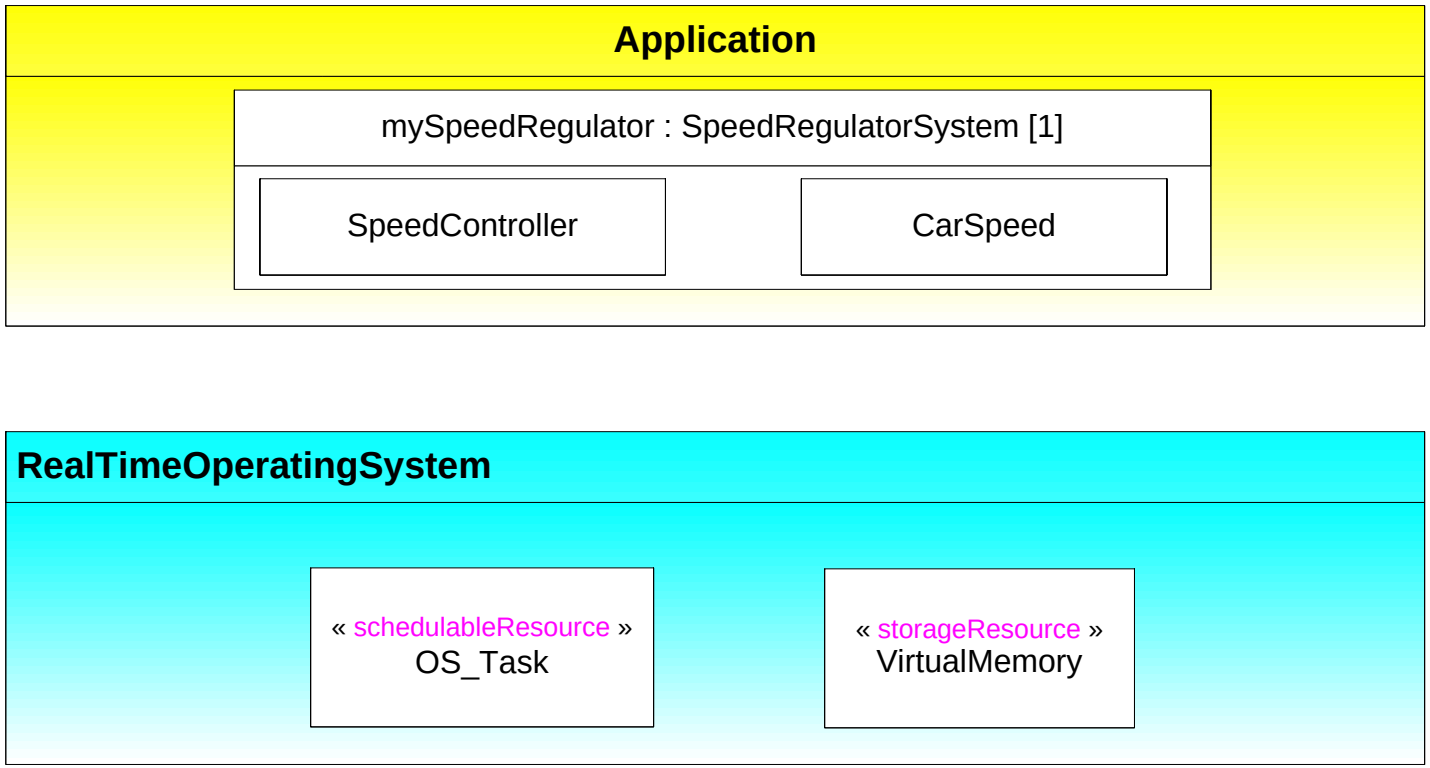


What can serve as a target of an allocation, the physical view:
➔ a resource or a service.

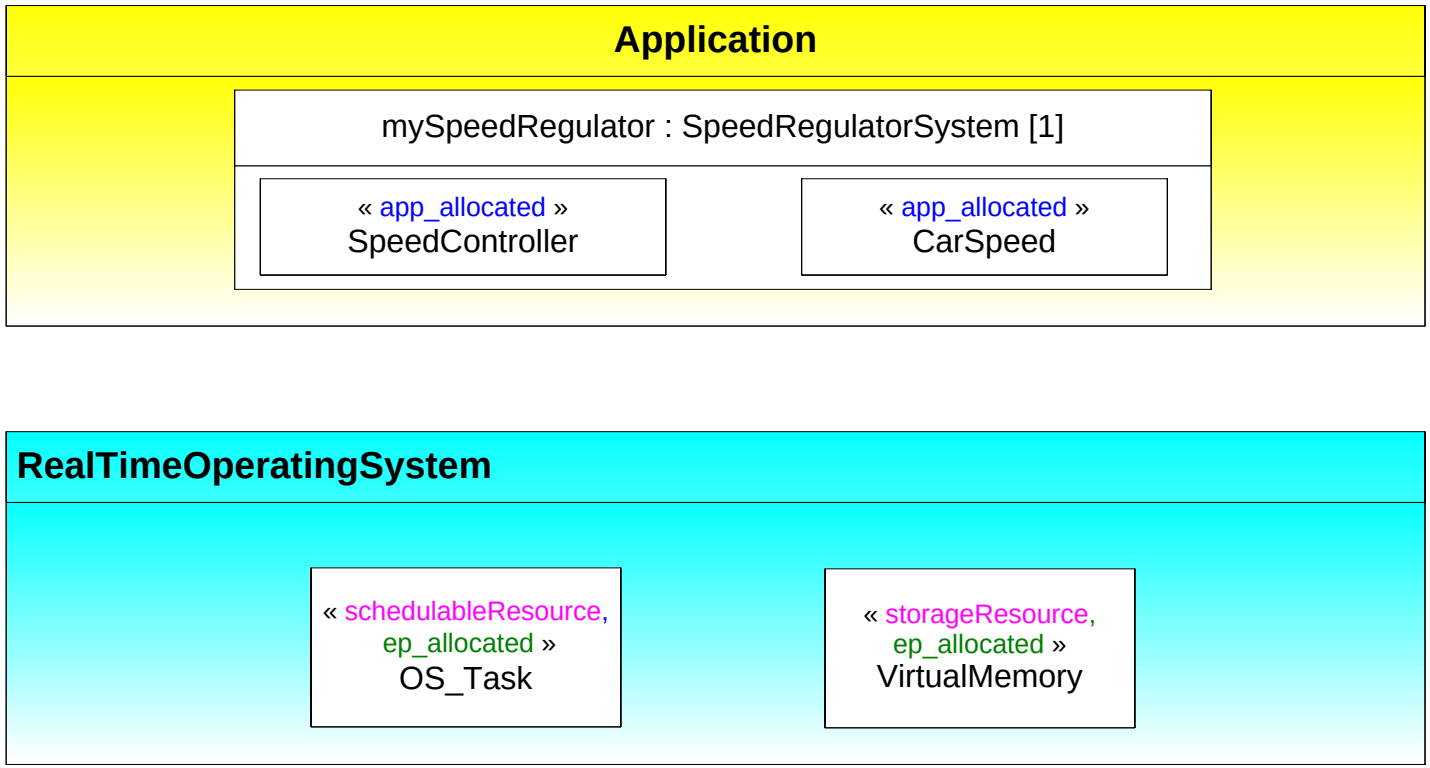
- **Define allocation relationships and its features**



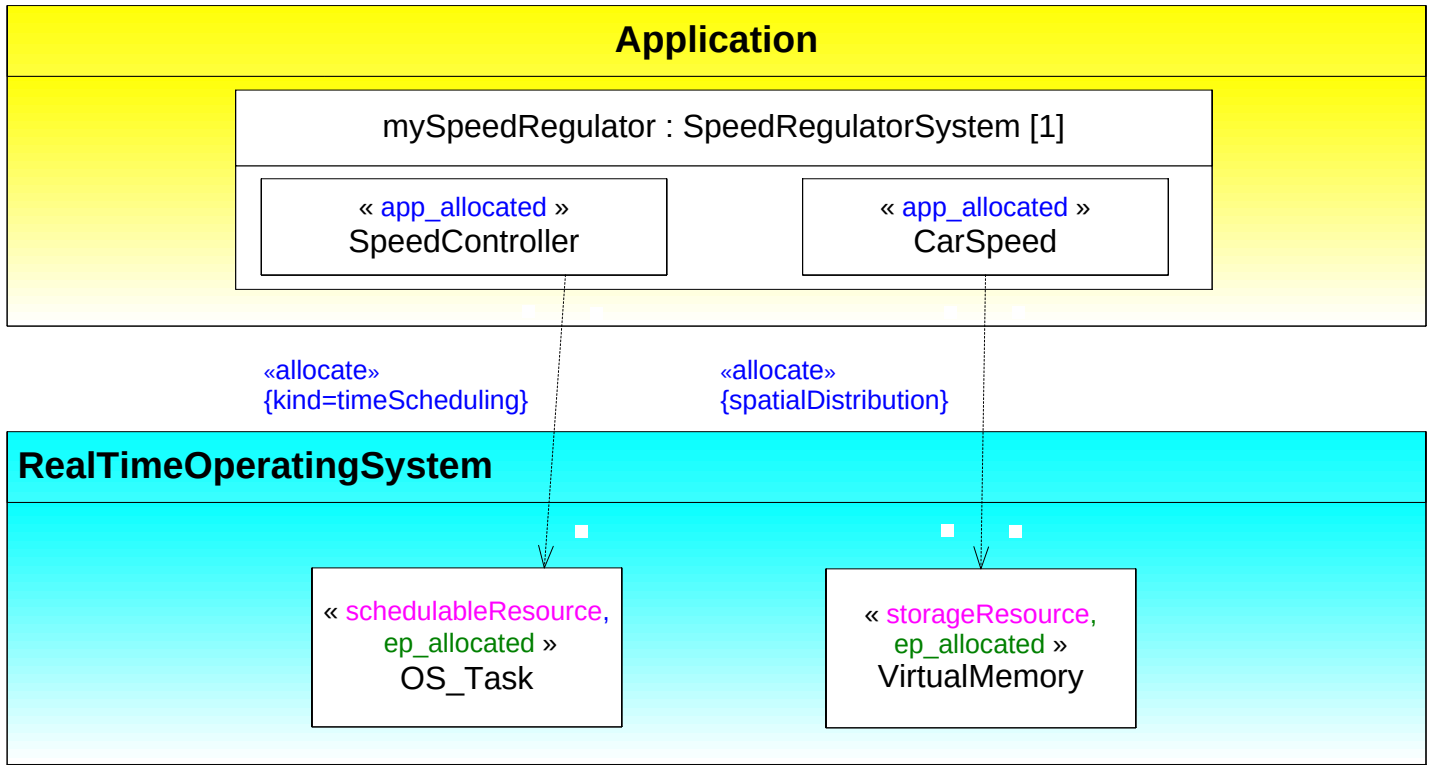
Allocation example (1)



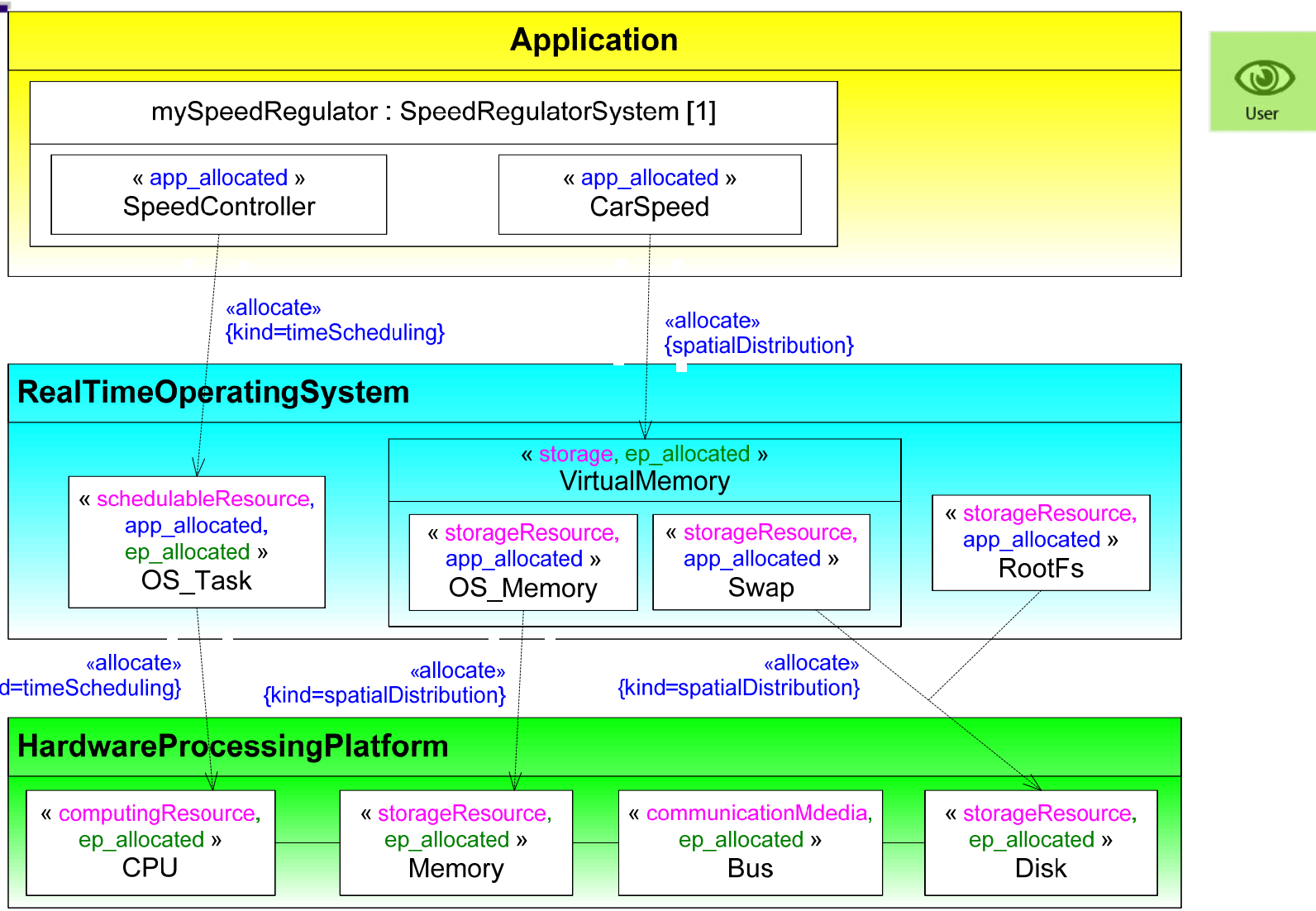
Allocation example (2)



Allocation example (3)



Allocation example (4)

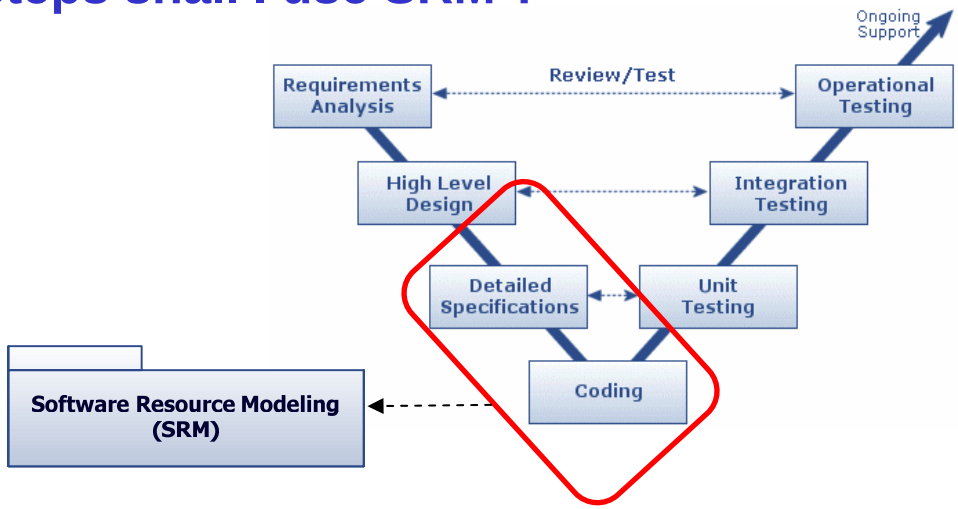


What is the Software Resource Modeling Profile (SRM) ?

- **A UML profile for modeling APIs of RT/E sw execution supports**
  - Real Time Operating Systems (RTOS)
  - Dedicated Language Libraries (e.g. ADA)
- **BUT it is NOT a new API standard dedicated to the RT/E domain!**
  - SRM is the result of a very deep state of the art/practices including but not limited to:
    - POSIX, ARINC 653, SCEPTRE, Linux RT, …

➔ SRM = a unified mean to describe such standard or proprietary APIs

- **In which steps shall I use SRM ?**



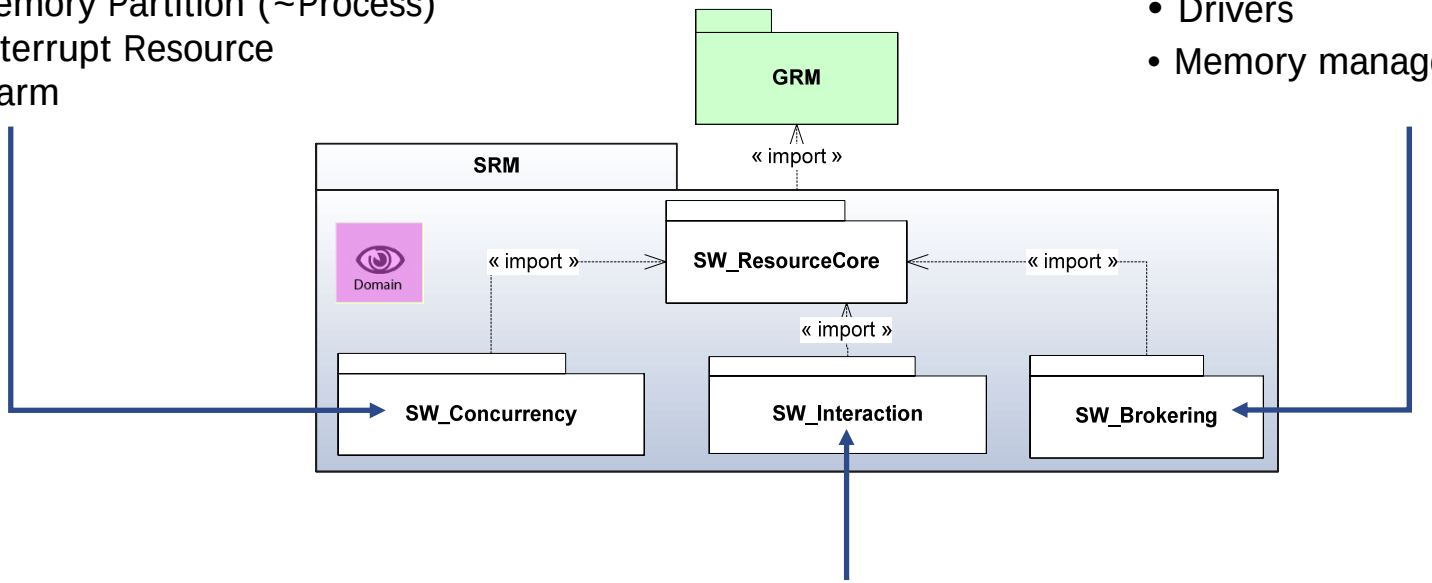
What is supported by the SRM profile ?

Concurrent execution contexts:

- Schedulable Resource (~Task)
- Memory Partition (~Process)
- Interrupt Resource
- Alarm

Hardware and software resources brokering:

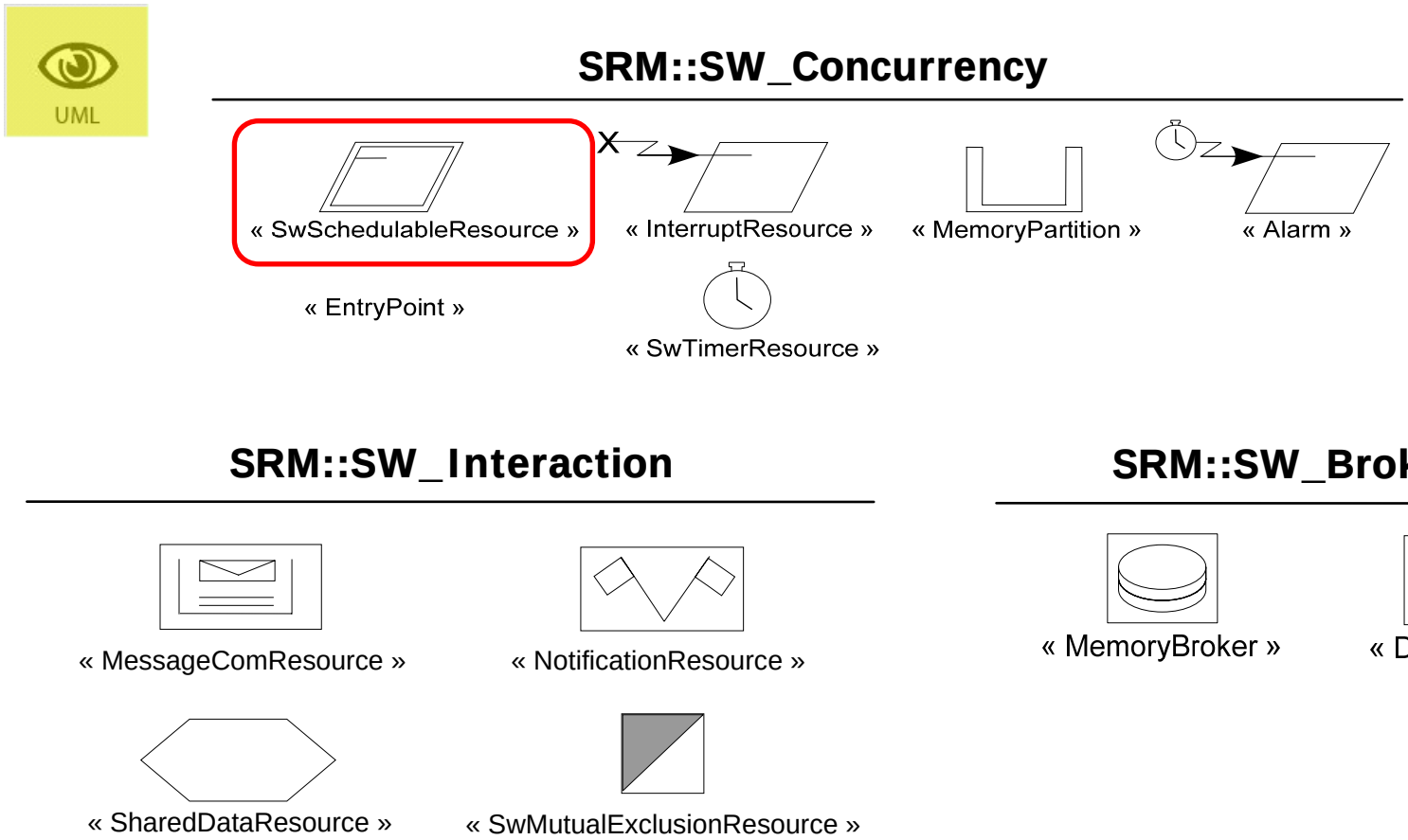
- Drivers
- Memory management



Interactions between concurrent contexts:

- Communication
  - ✓ Shared data
  - ✓ Message (~Message queue)
- Synchronization
  - ✓ Mutual Exclusion (~Semaphore)
  - ✓ Notification Resource (~Event mechanism)

Snapshot of the UML extensions provided by SRM



The OSEK/VDX case study

- **OSEK/VDX standard (http://www.osek-vdx.org)**
  - Automotive industry a standard for an open-ended architecture for distributed control units in vehicles
  - OSEK/VDX architecture consists of three layers:
    - OSEK-COM layer: Communication
      - **Data exchange support within and between electronics control units (ECUs)**
    - OSEK-NM layer : Network Management
      - **Configuration determination and monitoring**
    - OSEK-OS layer: Operating System
      - **API specification of RTOS for automotive ECU**

Overview of the OSEK/VDX-OS layer

- Main characterisics
  - A single processor operating system
  - A static RTOS where all kernel objects are created at compile time
- Main artifacts
  - Support for concurrent computing
    - **Task**
      - A task provides the framework for the execution of functions
    - **Interrupt**
      - Mechanism for processing asynchronous events
    - **Alarm & Counter**
      - Mechanisms for processing recurring events
  - Support for synchronizations of concurrent computing
    - **Event**
      - Mechanism for concurrent processing synchronization
    - **Resource**
      - Mechanism for mutual concurrent access exclusion

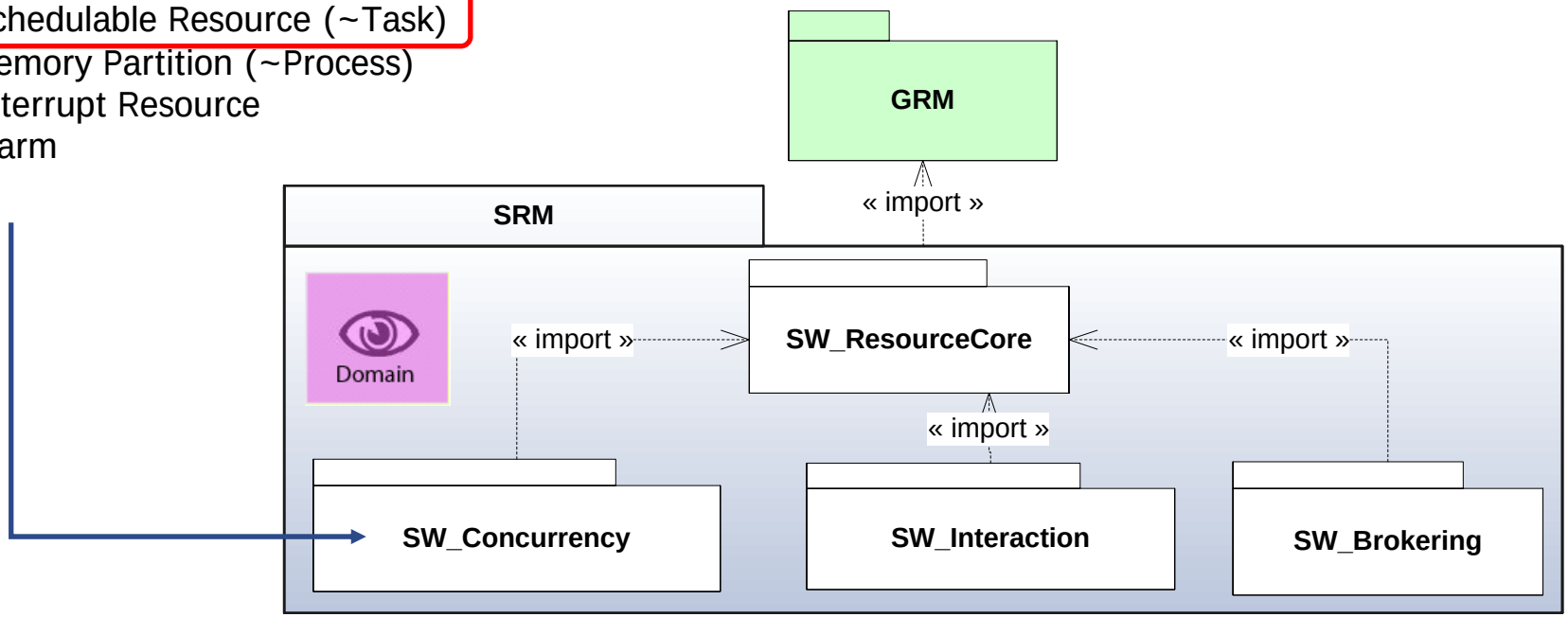
Focus on the OSEK/VDX Task definition

- **Semantic**
  - An OSEK-VDX task provides the framework for computing application functions. A scheduler will organize the sequence of task executions.
- **Example of properties**
  - **Priority: UINT32**
    - Priority execution of the task
  - **StackSize: UINT32**
    - Stack size associated to the execution of the task
- **Example of provided services**
  - **ActivateTask (TaskID: TaskType)**
    - Switch the task, identified by the **TaskID** parameter, from suspended to ready state
  - **ChainTask (TaskID: TaskType)**
    - Terminate of the calling task and activate the task identified by the **TaskID** parameter

Which SRM concepts for OSEK Task?

Concurrent execution contexts:

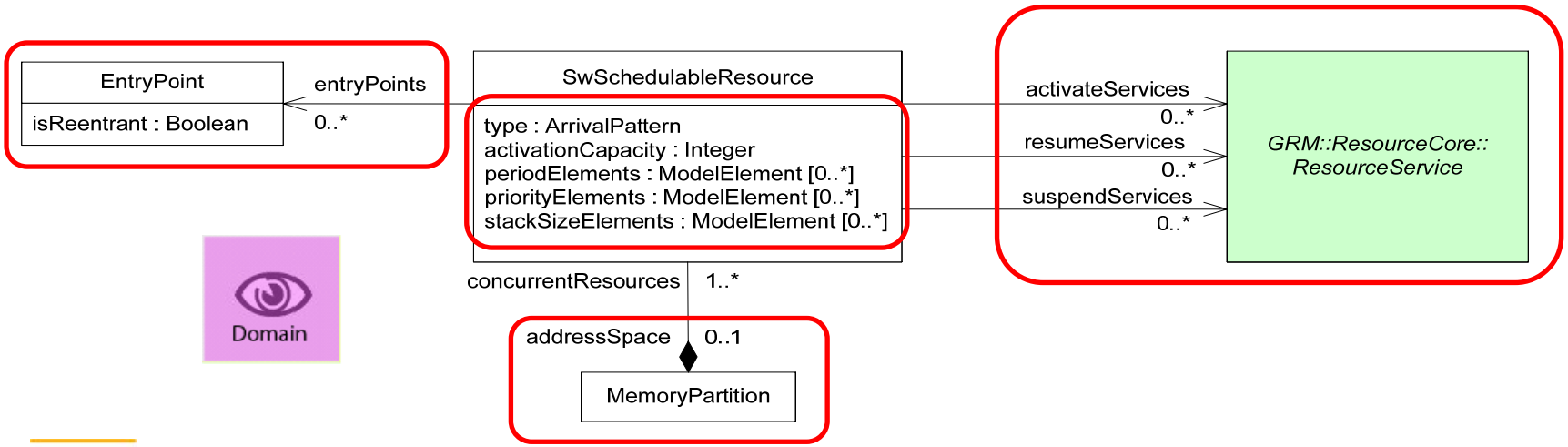
- Schedulable Resource (~Task)
- Memory Partition (~Process)
- Interrupt Resource
- Alarm



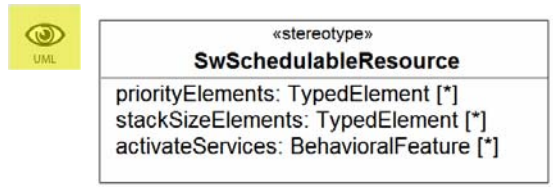
Details of «SwSchedulableResource»

- **Semantic (from MARTE::SRM::Concurrency package)**
  - Resource which executes, periodically or not, concurrently to other concurrent resources

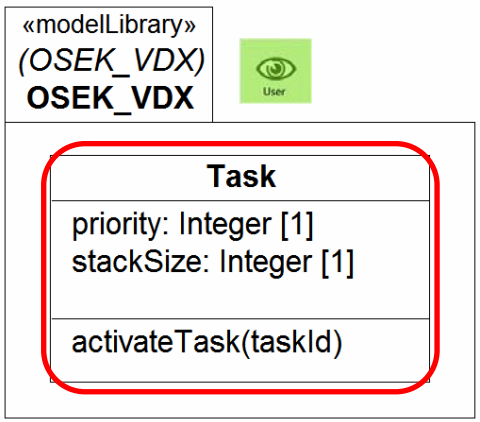
  ==> SRM artifacts for modeling OSEK-VDX Task!
- **Main features**
  - Owns an entry point referencing the application code to execute
  - May be restricted to execute in a given address space (i.e. a memory partition)
  - Owns properties: e.g., Priority, Deadline, Period and StackSize
  - Provides services: e.g., activate, resume and suspend
- **Extract from the SRM::SwConcurrency meta model**



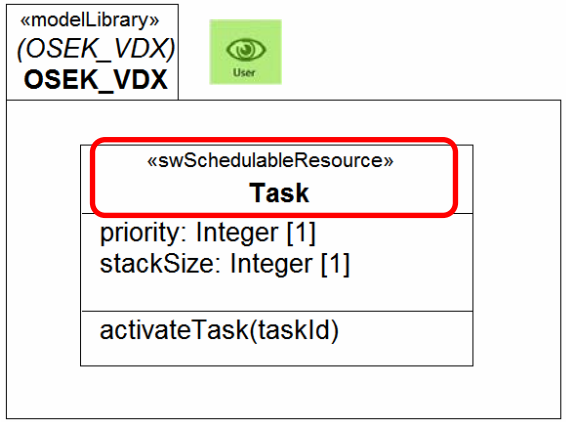
Model of an OSEK Task with «SwSchedulableResource»



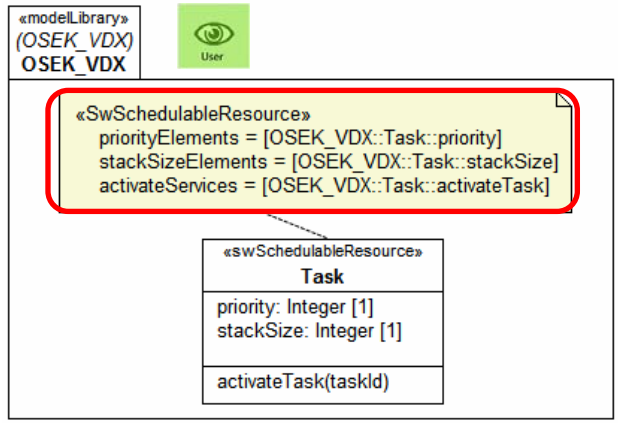
- **Define a UML model for OSEK_VDX::Task**
  a. Add model library applying the SRM profile
  b. Add a class and defines its features (properties and operations)
- **Applying the «SwSchedulableResource» stereotype**
- **Fullfill the tagged values of the applied stereotype**



(Step 1)



(Step 2)



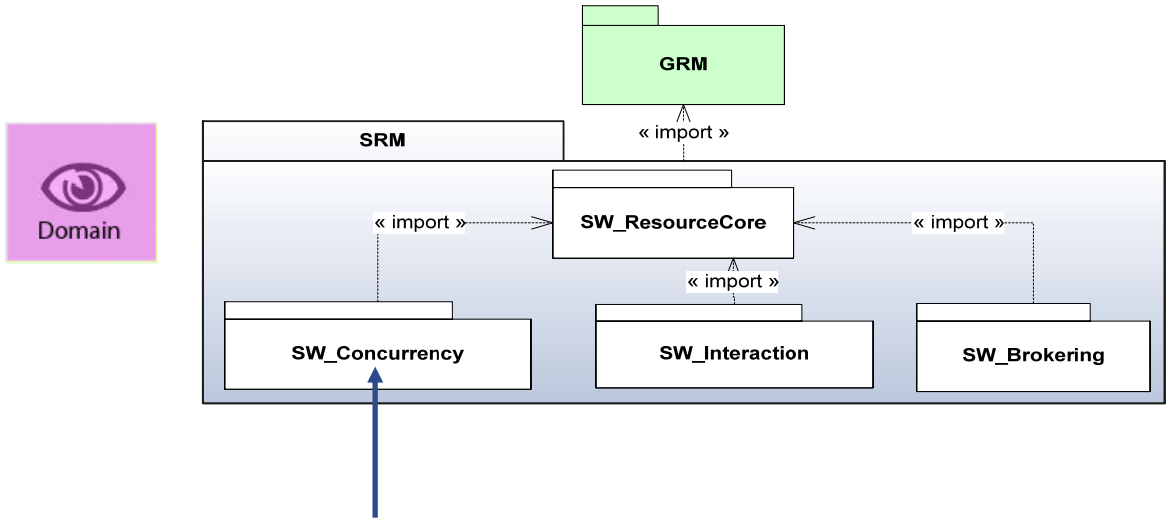
(Step 3)

Models have been realized with the Papyrus Eclipse-based open-source tool for UML2: http://www.papyrusuml.org

Focus on the OSEK/VDX Event definition

- **Semantic :**
  - The event mechanism is a means of synchronisation that initiates state transitions of tasks to and from the *waiting* state.
  - Example of owned properties
    - **Mask : EventMaskType**
      - **Define the mask associated with the event**
  - Examples of provided services
    - **SetEvent (TaskID: TaskType, Mask: EventMaskType)**
      - **The events of the task referenced by the** TaskID **parameter are set according to the event mask specified by the** Mask **parameter**.
      - **Calling the service** SetEvent **causes the task identified by the** TaskID **parameter to be transferred to the ready state, if it was waiting for at least one of the events specified in the** Mask **parameter**.
    - **WaitEvent (Mask: EventMaskType)**
      - **The state of the calling task is set to *waiting*, unless at least one of the events specified in the** Mask **parameter has already been set.**

Which SRM concepts for OSEK Event?



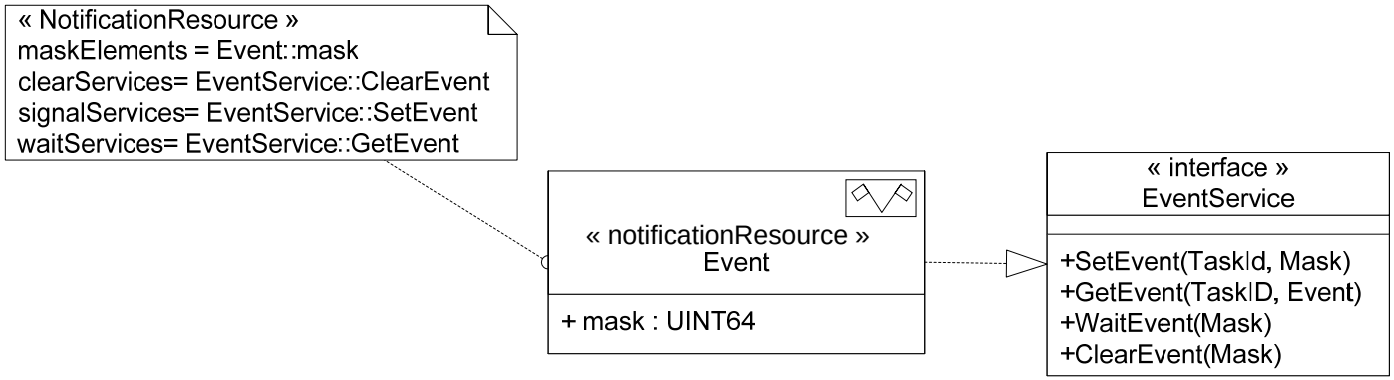
Interactions between concurrent contexts:

- Communication
  - ✓ Shared data
  - ✓ Message (~Message queue)
- Synchronization
  - ✓ Mutual Exclusion (~Semaphore)
  - ✓ Notification Resource (Event mechanism)

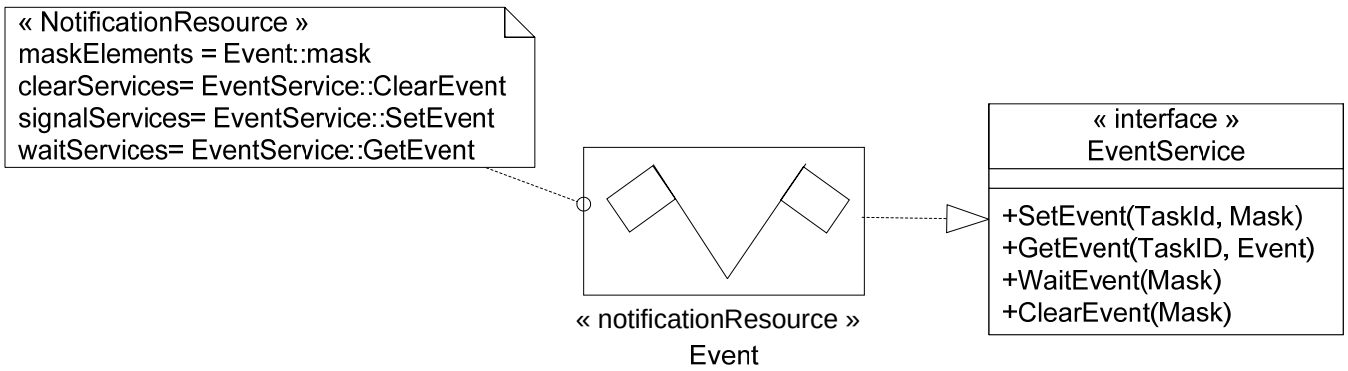
OSEK/VDX Event as a NotificationResource

User

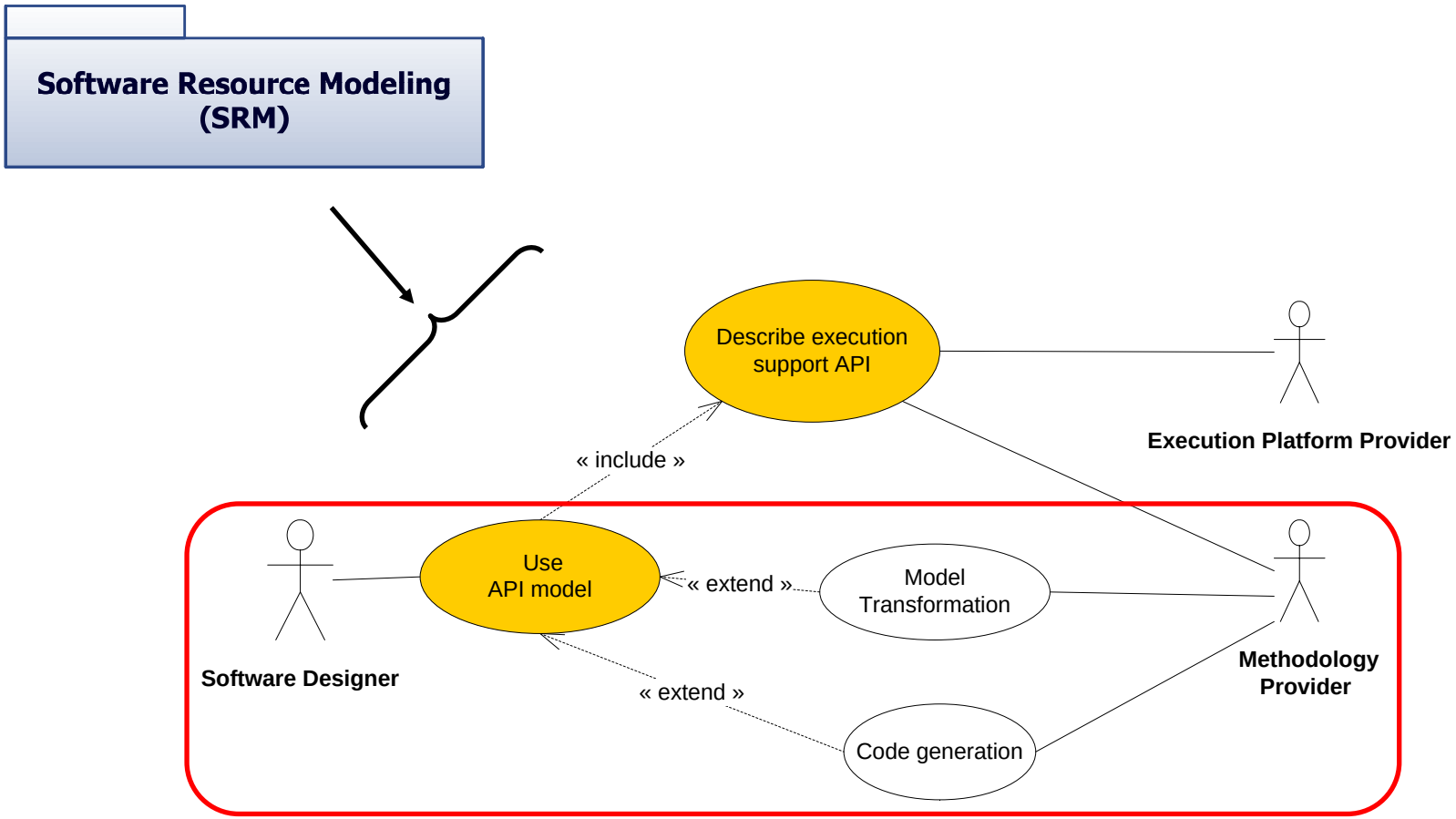
- **Stereotype icon**



- **Stereotype shape**



In which typical cases shall I use SRM ?

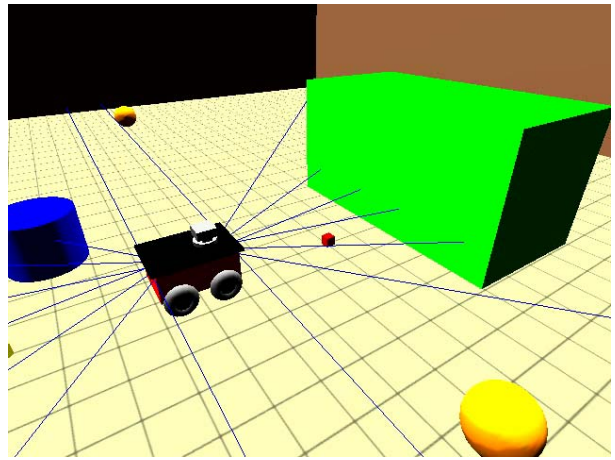


Use examples of one RTOS modeled with SRM

- **Example 1: Model-based design of multitask applications**
  - Illustrated on a robot controller application
- **Example 2: OS configuration file generation**
  - Generation of the OSEK OIL configuration files

Case study: A simple robot controller software

- **Goal**
  - A motion controller system for an exploration autonomous mobile robot.
- **Robot features**
  - Pioneer Robot (P3AT)
    - Four driving wheels
    - A camera
    - Eight sonar sensors, etc.
- **Design features of the robot controller**
  - OSEK/VDX execution support
    - Simulation on Trampoline (http://trampoline.rts-software.org/)
  - Two periodic tasks
    - **Data acquisition task**
      - Get position data from sonar sensors every 1 ms
    - **trajectory computing task**
      - Set new speed every 4 ms



Robot Simulator
http://playerstage.sourceforge.net/gazebo/gazebo.html

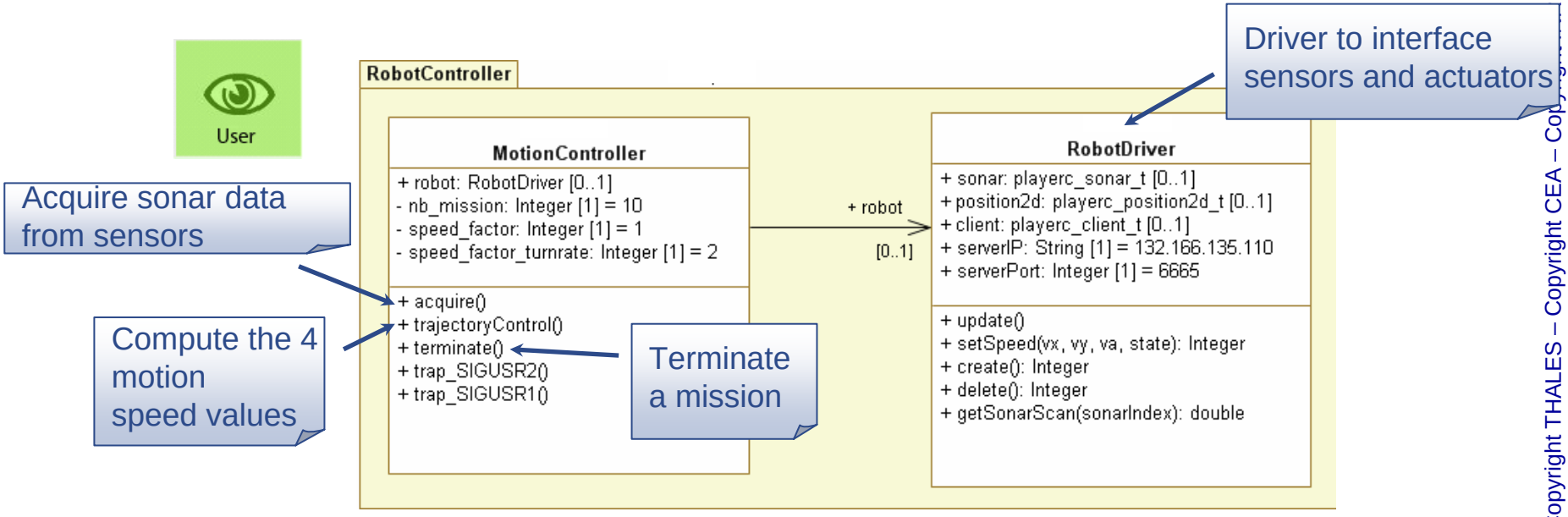
Purpose and context of the example 1

- **Provide a multitask design of the robot controller**
  - Target of the design is an OSEK/VDX-based platform

- **Design process**
  - A platform provider supplies the OSEK/VDX model library
    - Model library is described with the SRM Profile (as previously shown)
  - A user designs a multitask model of the application
    - Step 1: Describe the application model (also called functional model)
    - Step 2: Propose a multitask design using the OSEK model library artifact

Application design

- **Application model at the functional level**
  - One robot controller entity
    - Aims at controlling the robot motions
    - Main functions
      - **Acquire the sonar data**
      - **Compute the new speed of each 4 motions and send new orders**
  - A robot driver entity
    - Aims at interfacing robot sensors and actuators with the control application

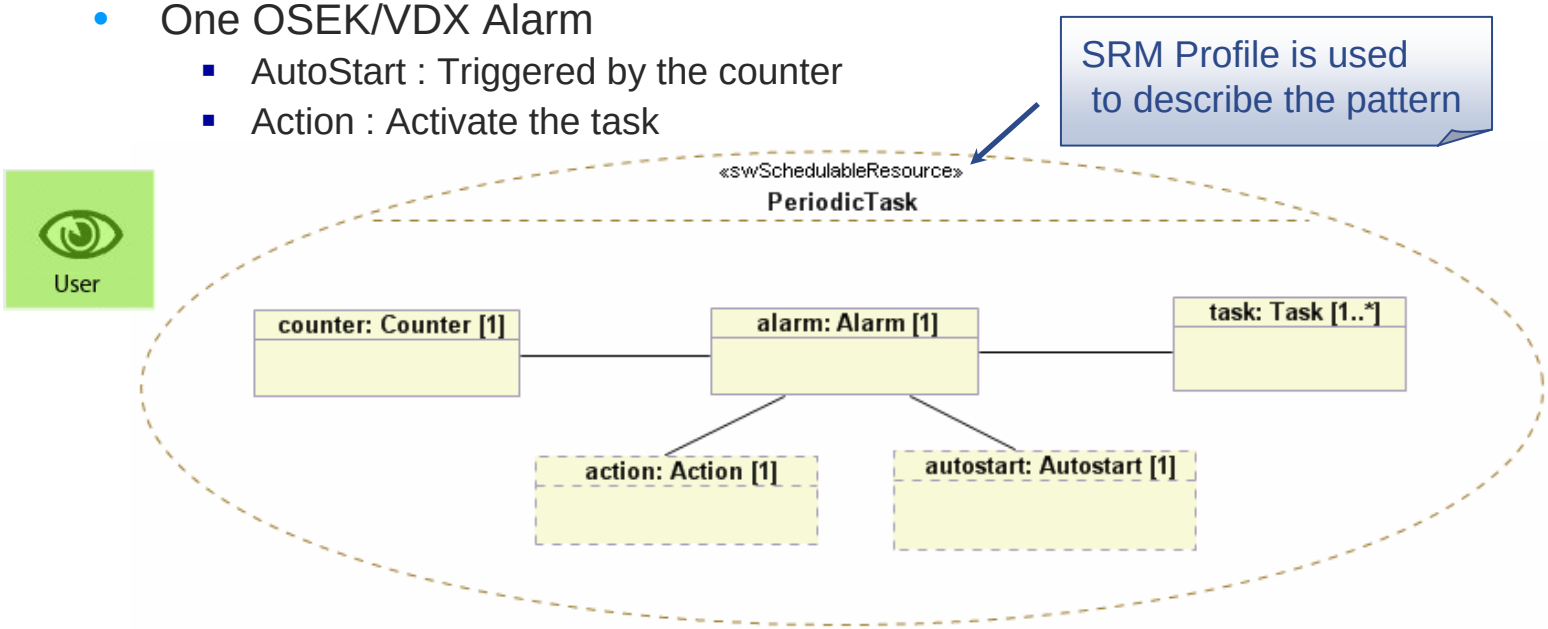


Principles of the applied multitask design

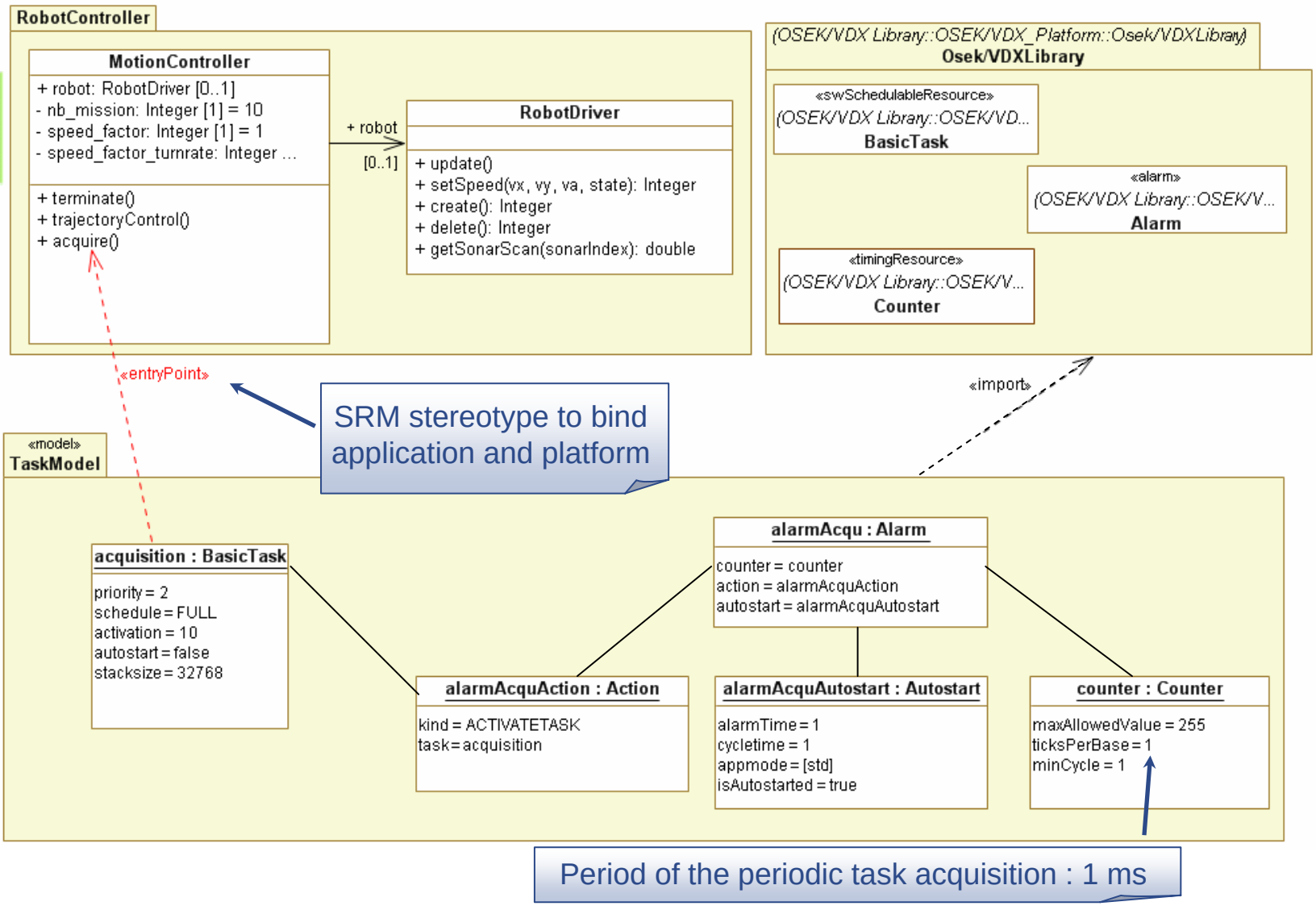
- **Two periodic tasks**
  - For data acquisition
    - Get position data from sonar sensors
    - Entry point
      - **Operation MotionController::acquire()**
    - Periodic
      - **Period = 1 ms**
  - For trajectory control
    - Compute and assign new speed order
    - Entry point
      - **Operation MotionController::trajectoryControl()**
    - Periodic
      - **Period = 4 ms**

Periodic task in OSEK/VDX

- **A design pattern for implementing periodic task on OSEK/VDX-based platforms**
  - One OSEK/VDX Counter
    - Counter period = period of the required periodic task
  - One OSEK/VDX Task
    - Entry point : periodic task Entry Point
  - One OSEK/VDX Alarm
    - AutoStart : Triggered by the counter
    - Action : Activate the task



Basic Robot Controller task models



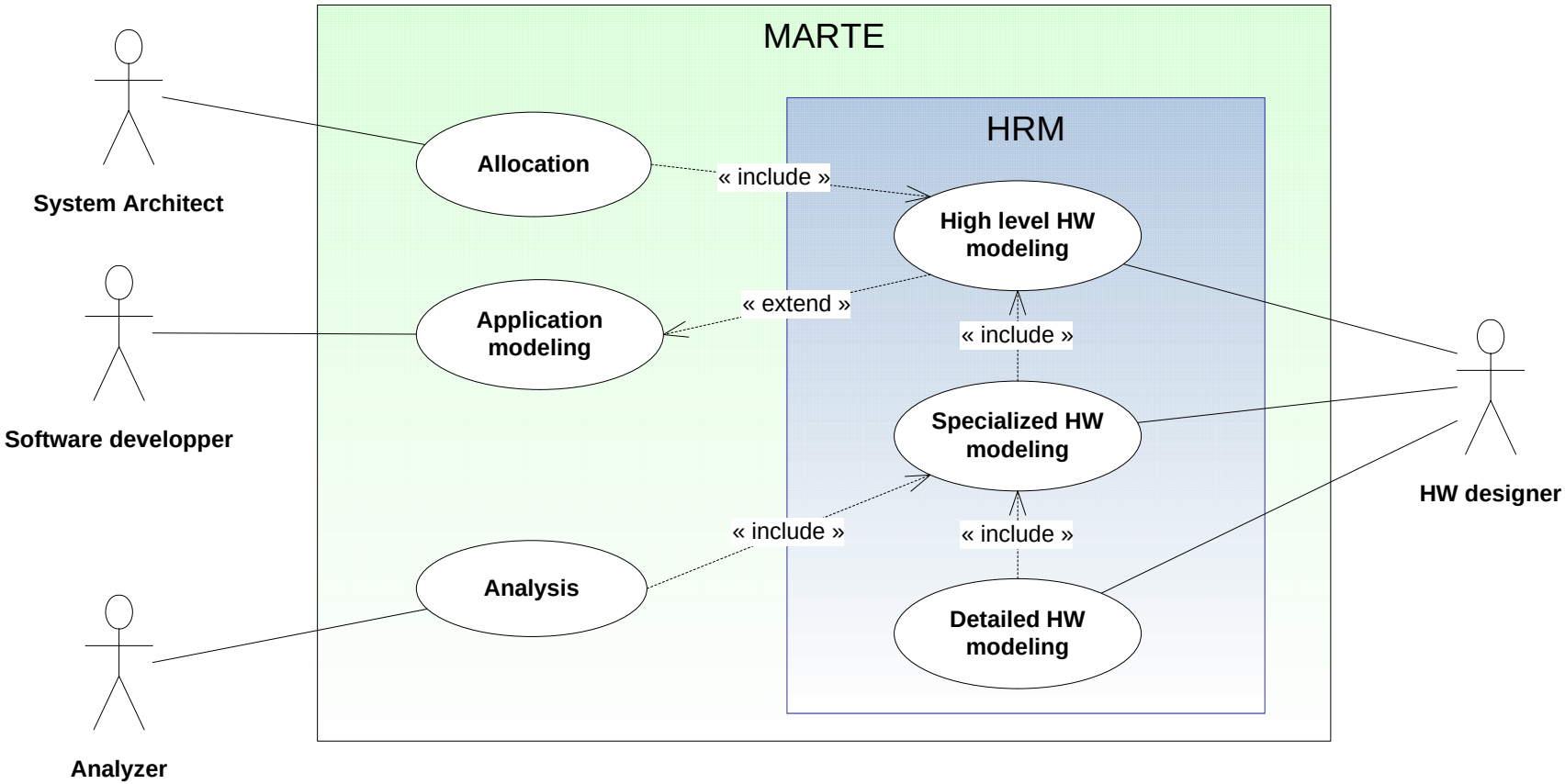
Example 2: OSEK Configuration File generation

- **Purpose**
  - Generation of the OSEK OIL configuration files from the multi-task design of the robot controller
- **OIL: OSEK Implementation Language**
  - http:://osek-vdx.org
  - The goal of OIL is to provide a mechanism to configure an OSEK application for a particular CPU
  - Principle
    - For each CPU, there must be an OIL description
    - All OSEK system objects are described using OIL objects
    - OIL descriptions may be :
      - **hand-written**
      - **or generated by a system configuration tool**

```
OIL_VERSION = "2.5" : "RobotController" ;

IMPLEMENTATION OSEK {
};

CPU cpu {
  APPMODE std {
  };

  COUNTER counter {
                MAXALLOWEDVALUE =  255 ;
                TICKSPERBASE =  1 ;
                MINCYCLE =  1 ;
  };
  ALARM alarmAcqu {
                COUNTER =  counter ;
                ACTION =  ACTIVATETASK {
                              TASK =  acquisition ;
                } ;
                AUTOSTART =  TRUE {
                              ALARMTIME =  1 ;
                              CYCLETIME =  1 ;
                              APPMODE =  std ;
                } ;
  };

  TASK acquisition {
                PRIORITY =  2 ;
                SCHEDULE =  FULL ;
                ACTIVATION =  10 ;
                AUTOSTART =  FALSE ;
                STACKSIZE =  32768 ;
  };
...
```

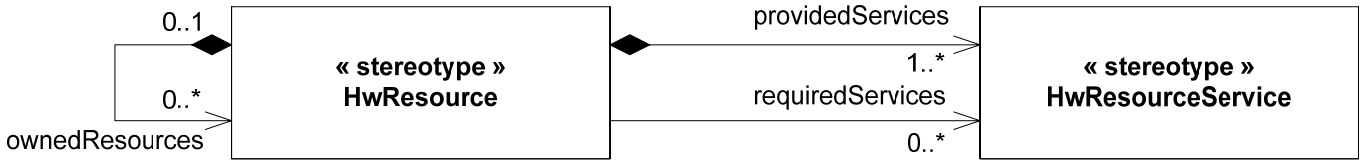
HRM use cases

3 use cases = 3 levels of details



HRM structure

- **Hierarchical taxonomy of hardware concepts**
  - Successive **inheritance** layers
  - **From** generic concepts (GRM-like)
    - *HwComputingResource, HwMemory, HwCommunicationResource…*
  - **To** specific and detailed resources
    - *HwProcessor, HwBranchPredictor, HwCache, HwMMU, HwBus, HwBridge, HwDMA…*
  - All HRM concepts are *HwResource(s)*



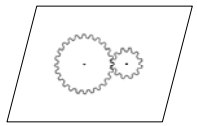
- Two **modeling** views **to separate concerns**

Logical / Physical

HRM structure -- Logical modeling

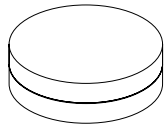
- **Provides a functional description**
- **Based on a functional classification of hardware resources:**

. HwComputing .

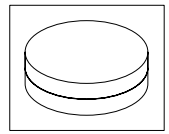


« HwProcessor », « HwPLD », « HwASIC »

. HwStorage .

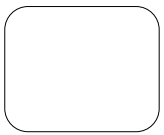


« HwCache », « HwRAM », « HwROM », « HwDrive »

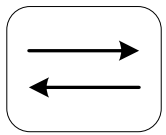


« HwMMU », « HwDMA »

. HwDevice .

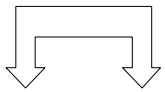


« HwDevice », « HwSupport »

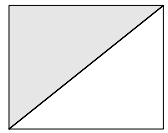


« HwI/O »

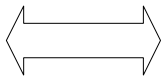
. HwCommunication .



« HwBridge »

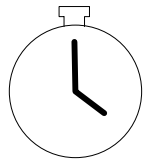


« HwArbiter »



« HwMedia », « HwBus »

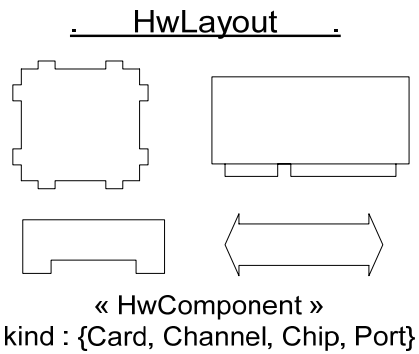
. HwTiming .

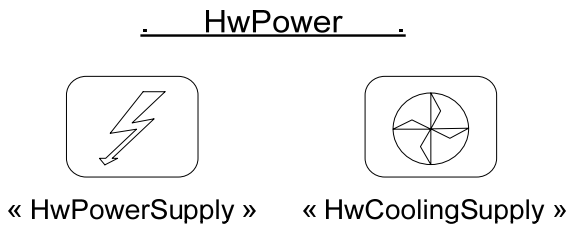


« HwClock », « HwTimer »

HRM structure -- Physical modeling

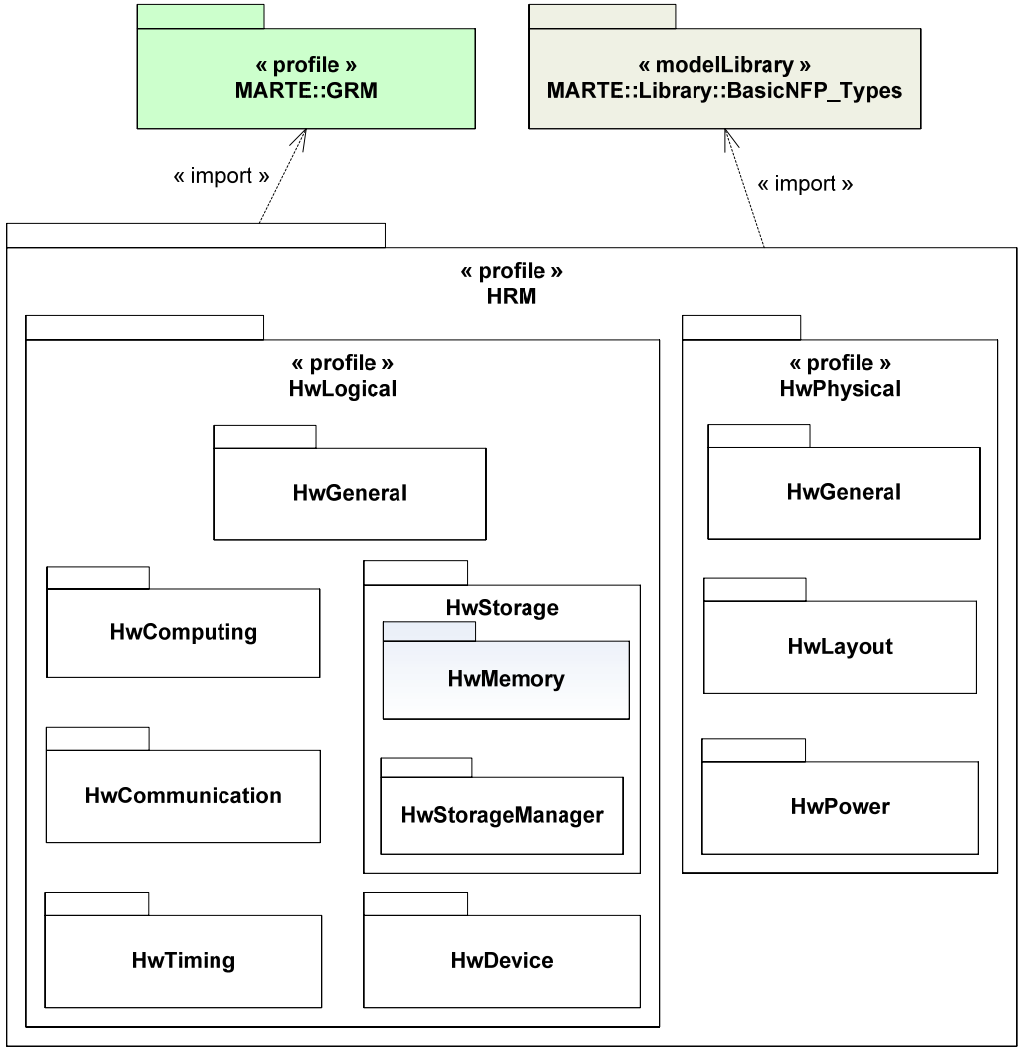
- **Provides a physical properties description**
- **Based on both following packages**
  - HwLayout
    - Forms: Chip, Card, Channel…
    - Dimensions, area and arrangement mechanism within rectilinear grids
    - Environmental conditions: e.g. temperature, vibration, humidity…
  - HwPower
    - Power consumption and heat dissipation



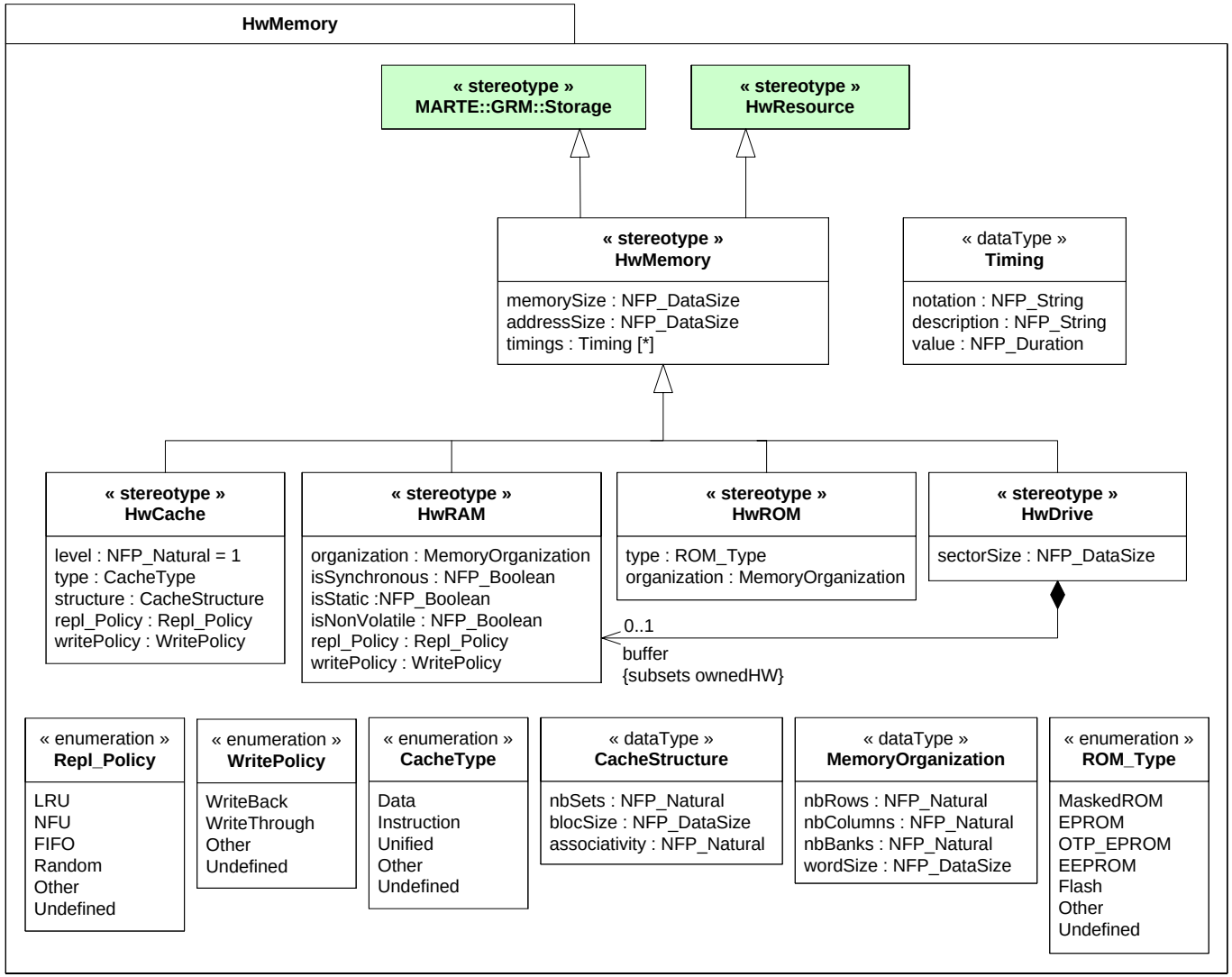


HRM profile overview

HRM profile -- HwMemory



HRM profile -- HwMemory



HRM profile -- HwMemory -- HwCache

« stereotype » **HwCache**
level : NFP_Natural = 1 type : CacheType structure : CacheStructure repl_Policy : Repl_Policy writePolicy : WritePolicy

- **HwCache is a processing memory where frequently used data can be stored for rapid access**
- **Detailed description of the HwCache is necessary for performance analysis and simulation**

« enumeration » **Repl_Policy**
LRU NFU FIFO Random Other Undefined

« enumeration » **WritePolicy**
WriteBack WriteThrough Other Undefined

« enumeration » **CacheType**
Data Instruction Unified Other Undefined

« dataType » **CacheStructure**
nbSets : NFP_Natural blocSize : NFP_DataSize associativity : NFP_Natural

HRM profile -- HwMemory -- HwCache

« stereotype » **HwCache**
level : NFP_Natural = 1 type : CacheType structure : CacheStructure repl_Policy : Repl_Policy writePolicy : WritePolicy

- **Specifies the cache level.**
  - Default value is 1

« enumeration » **Repl_Policy**
LRU NFU FIFO Random Other Undefined

« enumeration » **WritePolicy**
WriteBack WriteThrough Other Undefined

« enumeration » **CacheType**
Data Instruction Unified Other Undefined

« dataType » **CacheStructure**
nbSets : NFP_Natural blocSize : NFP_DataSize associativity : NFP_Natural

HRM profile -- HwMemory -- HwCache

« stereotype » **HwCache**
level : NFP_Natural = 1 type : CacheType structure : CacheStructure repl_Policy : Repl_Policy writePolicy : WritePolicy

- **Specifies the HwCache structure**
- **HwCache is organized under sets of blocks.**
- **Associativity is the number of blocks within each set.**
  - If associativity = 1, cache is direct mapped
  - If nbSets = 1, cache is fully associative.
- **OCL rule**
  - *memorySize = nbSets x blocSize x associativity*

« enumeration » **Repl_Policy**
LRU NFU FIFO Random Other Undefined

« enumeration » **WritePolicy**
WriteBack WriteThrough Other Undefined

« enumeration » **CacheType**
Data Instruction Unified Other Undefined

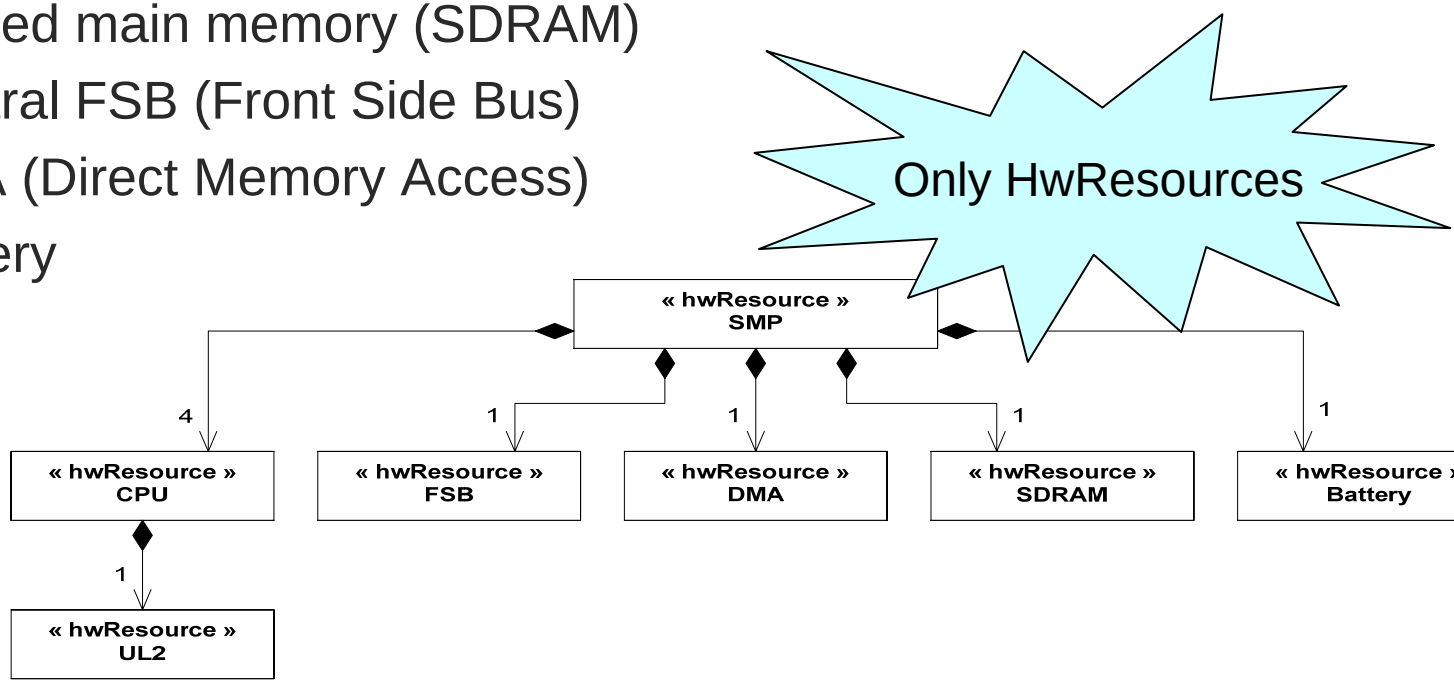
« dataType » **CacheStructure**
nbSets : NFP_Natural blocSize : NFP_DataSize associativity : NFP_Natural

HRM usage

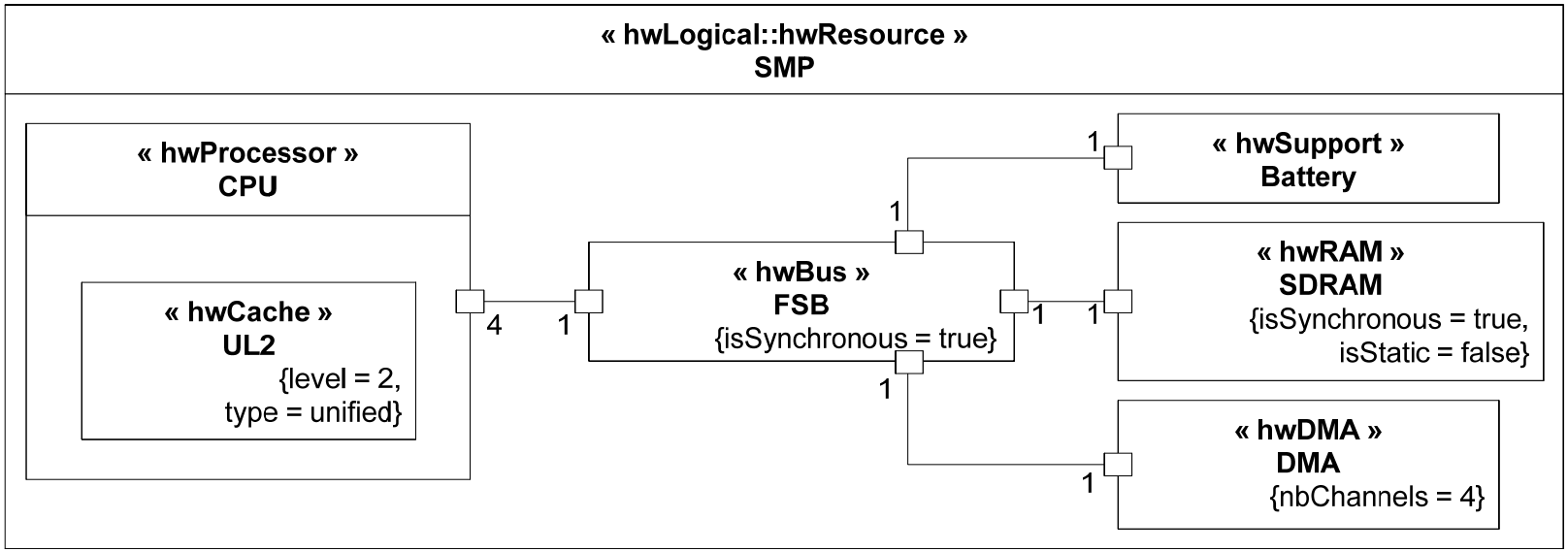
- **HRM stereotypes extends the main structural UML metaclasses**
  - Classifier, Class
  - InstanceSpecification, Property
  - Association (HwMedia, HwBus…), Port (HwEndPoint)
- **HRM can be used with all Structural UML diagrams:**
  - Class diagram
  - Component diagram
  - Composite Structure Diagram (well adapted for HW)
- **HRM profile application**
  - Definitions of the stereotype properties are optional
    - Specified **if** needed
    - Specified **when** needed (**Refinement**)
      - **At class level for technology definition (e.g. type of *HwCache*)**
      - **At instance level for component definition (e.g. size of *HwCache)***

Very early Hw Architecture Description

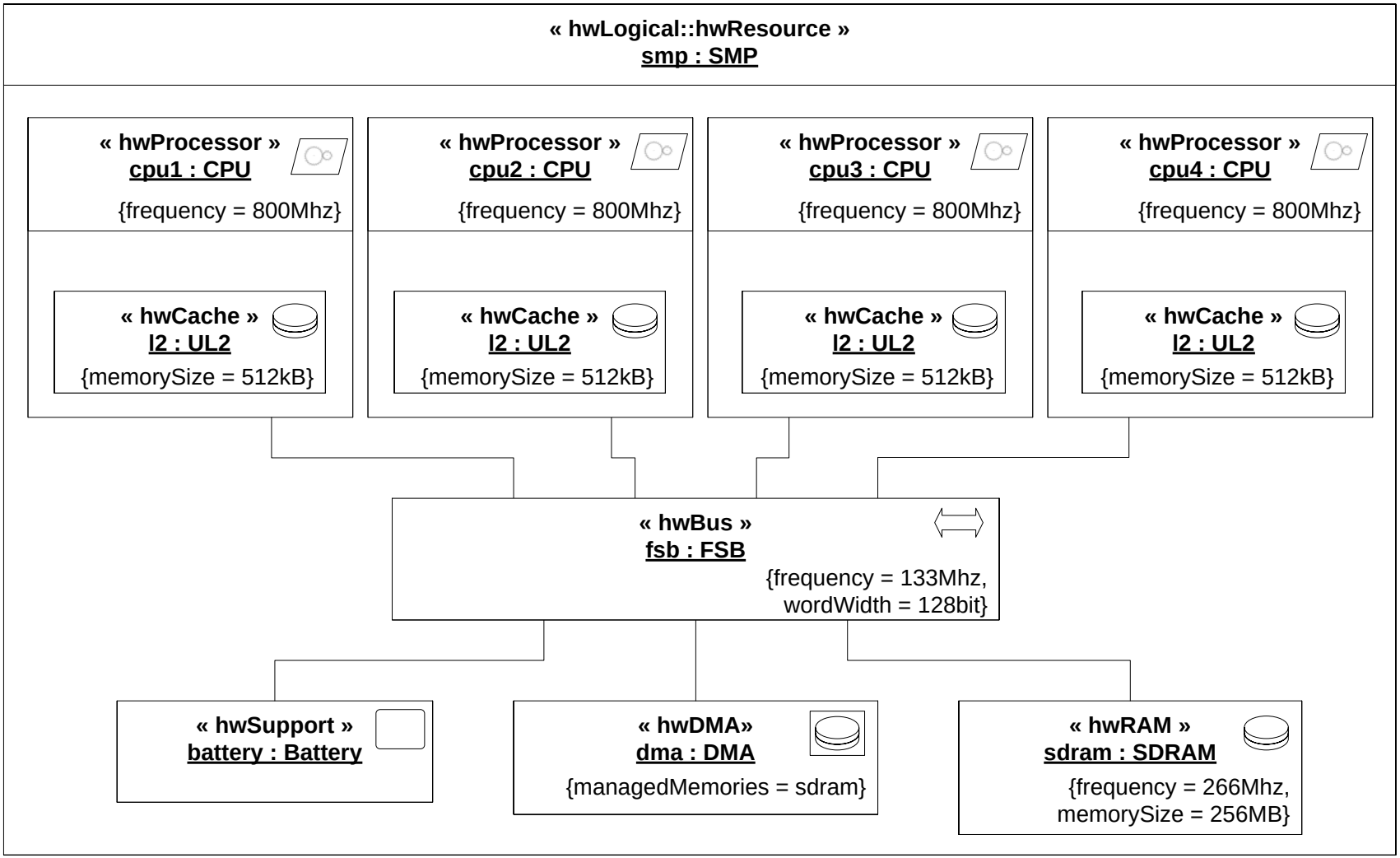
- **SMP (Symmetric MultiProcessing) hardware platform**
  - 4 identical processors
    - Unified Level 2 cache for each
  - Shared main memory (SDRAM)
  - Central FSB (Front Side Bus)
  - DMA (Direct Memory Access)
  - Battery



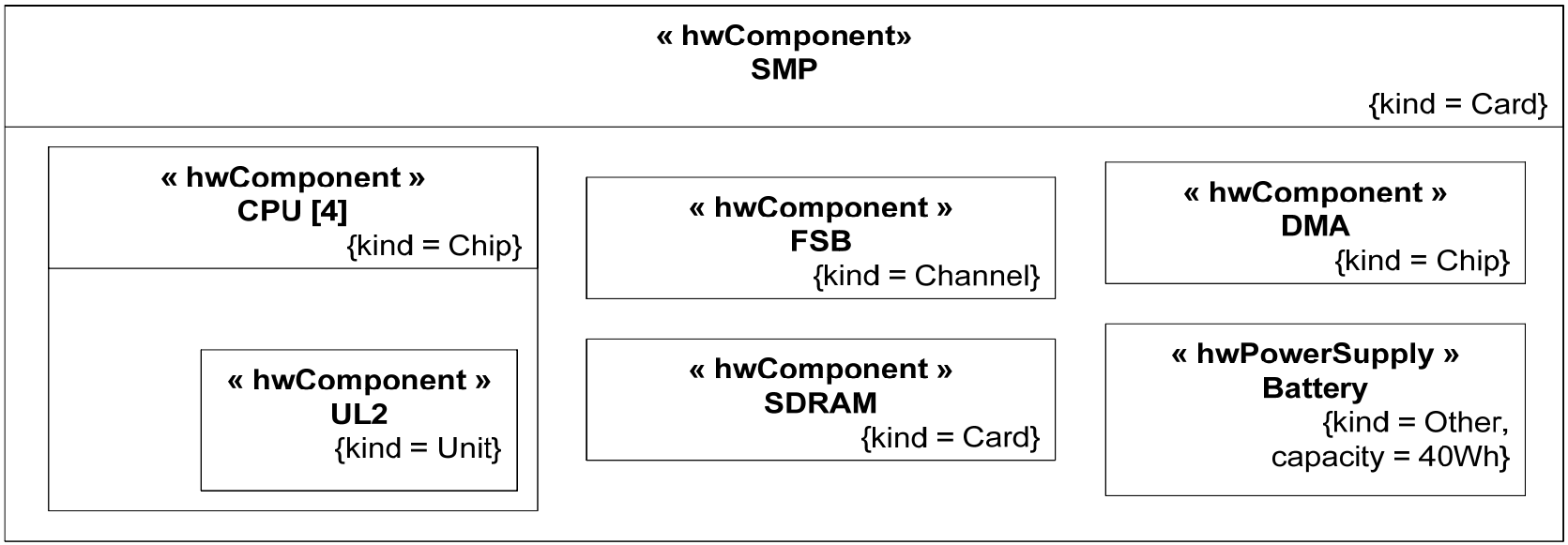
HRM usage example: Logical view 1



HRM usage example: Logical view 2



HRM usage example: Physical view 1



HRM usage example: Physical view 2