UML Profile for Modeling and Analysis of Real-time and Embedded Systems (MARTE) Tutorial

Software Resource Modeling

Workshop on Distributed Object Computing for Real-time and Embedded Systems

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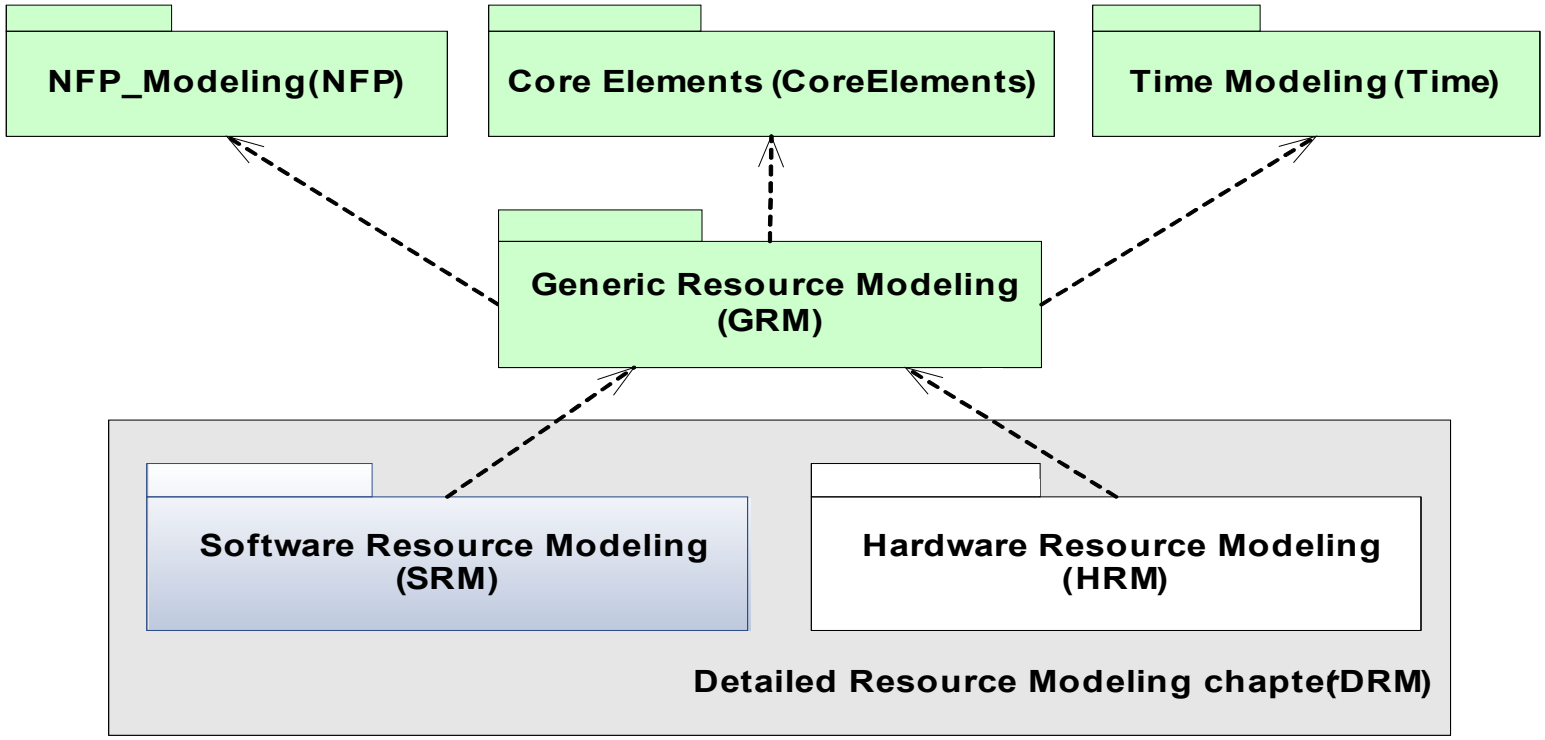
Outline

- SRM Overview
  - What is the SRM profile?
  - In which design steps shall I use SRM?
  - In which typical cases shall I use SRM?
- RTOS API modeling with SRM: the OSEK/VDX case study
  - Why shall I use SRM for RTOS API modeling?
  - OSEK/VDX overview
  - What is supported by the SRM profile?
  - The OSEK/VDX Task modeling with SRM
  - The OSEK/VDX Event modeling with SRM
- Examples of API model uses
  - A robotic case study
    - multitask model designs
    - OS configuration file generation
    - RTE application models porting

SRM overview

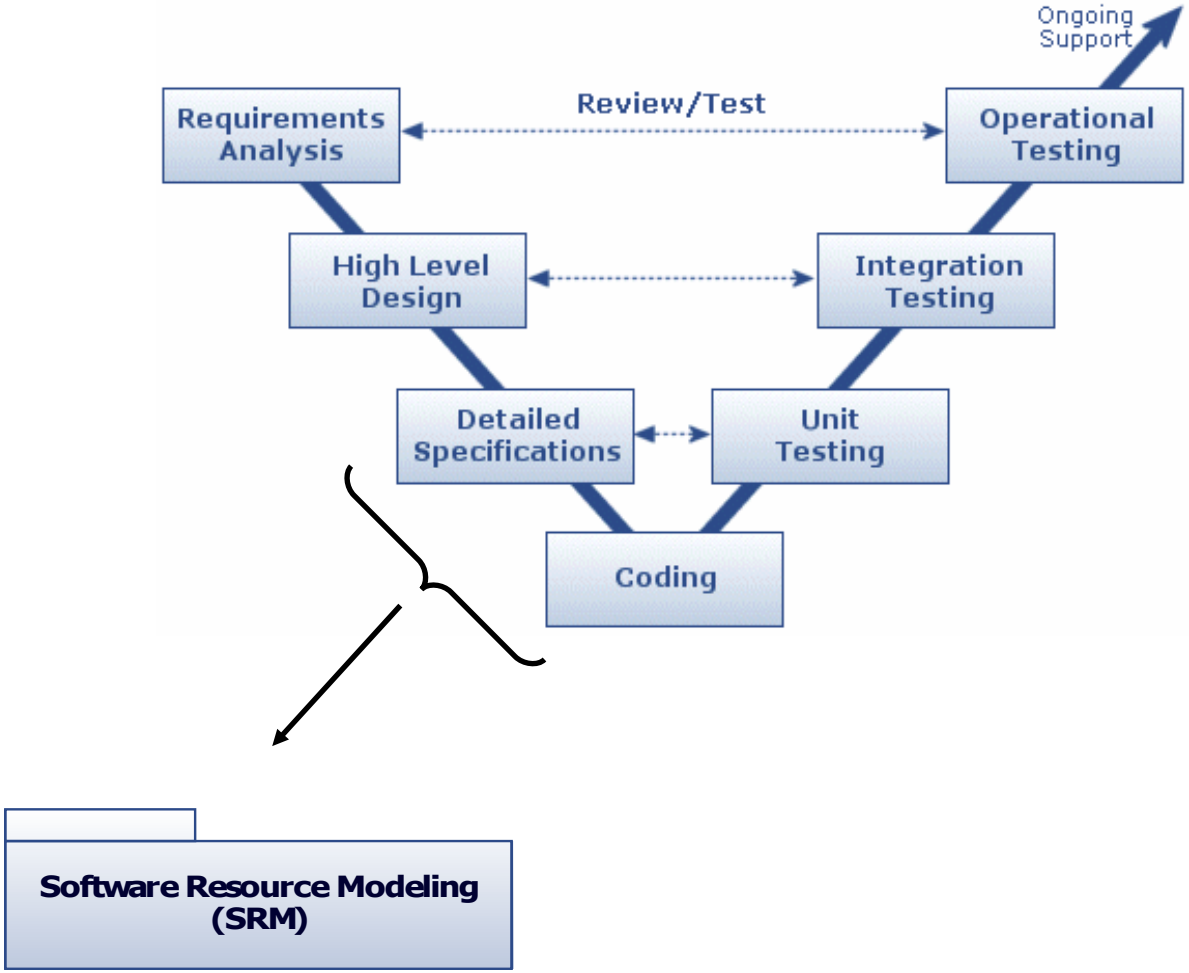


What is the SRM Profile ?

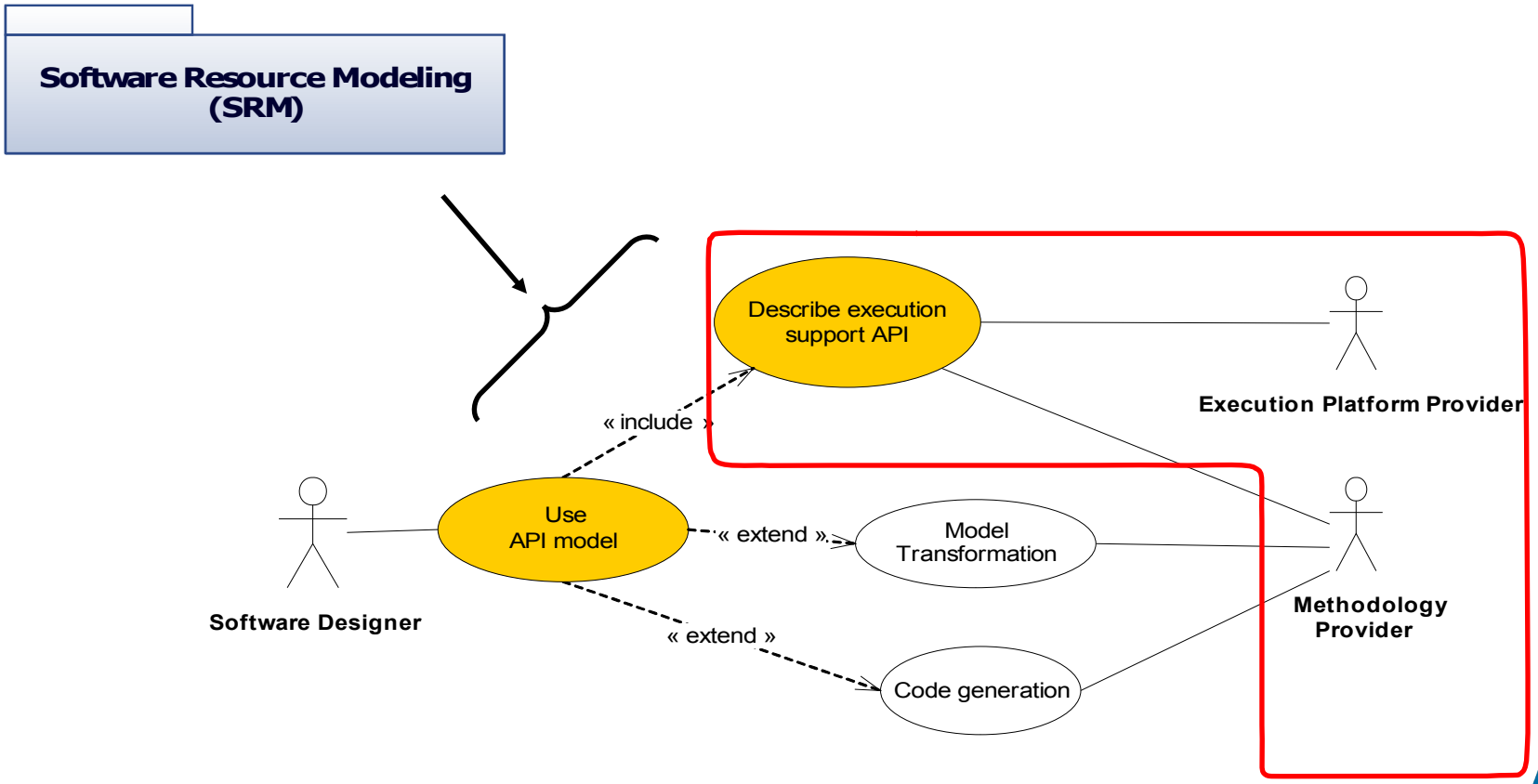
- **The Software Resource Modeling profile is**:
  - **A UML Profile to describe API of software execution supports**
    - Real Time Operating Systems (RTOS)
    - Language Libraries (e.g. ADA)

- **BUT**, the **SRM** profile **is not a new API standard dedicated to the Real-Time and Embedded domain.**
  - SRM allow users to describe RTE API involved in the design cycle
    - standard RTOS API (e.g. POSIX, OSEK/VDX and ARINC 653)

In which steps shall I use SRM ?



In which typical cases shall I use SRM ?



Why shall I use SRM for RTOS API modeling ?

- RTOS API modeling with UML is already possible
  - But,
    - UML core is lacking in some key RTE native artifacts
      - RTOS providers have no modeling artifacts to describe tasks, semaphores, mailboxes …
      - Methodology providers can't describe generic tools
        - » For each model they must describe specific generative tools (e.g. code generator, model transformations)
- SRM profile allows
  - To describe efficient and precise multitask models
  - To be able to describe generic generative tools
  - To describe models in an unified and standard way
    - SRM profile is a sub-profile of the MARTE standard

Execution support API modeling : the OSEK/VDX case study

- Let's take an example :
  - OSEK/VDX standard (http://www.osek-vdx.org)
    - It aims to provide to the automotive industry a standard for an open-ended architecture for distributed control units in vehicles
    - The open architecture introduced by OSEK/VDX comprises these three main areas:
      - OSEK COM : Communication (data exchange within and between control units)
      - OSEK NM : Network Management (Configuration determination and monitoring)
      - OSEK OS : Operating System (real-time execution of ECU software and base for the other OSEK/VDX modules)

OSEK/VDX OS Overview

- We mainly focus on OSEK OS 2.2.2 in this section.
  - A single processor operating system.
  - A static RTOS where all kernel objects are created at compile time.

- Mechanisms :
  - Concurrent execution mechanisms
    - Task
      - » A task provides the framework for the execution of functions
    - Interrupt
      - » Mechanism for processing asynchronous events
    - Alarm & Counter
      - » Mechanisms for processing recurring events
  - Synchronization mechanisms
    - Event
      - » Mechanism for concurrent processing synchronization
    - Resources
      - » Mechanism for mutual concurrent access exclusion

OSEK/VDX Task overview

- Semantics:
  - A task provides the framework for the execution of functions. The scheduler organizes the sequence of task execution.
  - Specific Properties :
    - **Priority**: UINT32
    - **StackSize**: UINT32
  - Specific Services :
    - **ActivateTask (TaskID)** : The task **<TaskID>** is transferred from the *suspended* state into the *ready* state
    - **ChainTask (TaskID)** : This service causes the termination of the calling task. After termination of the calling task a succeeding task **<TaskID>** is activated.

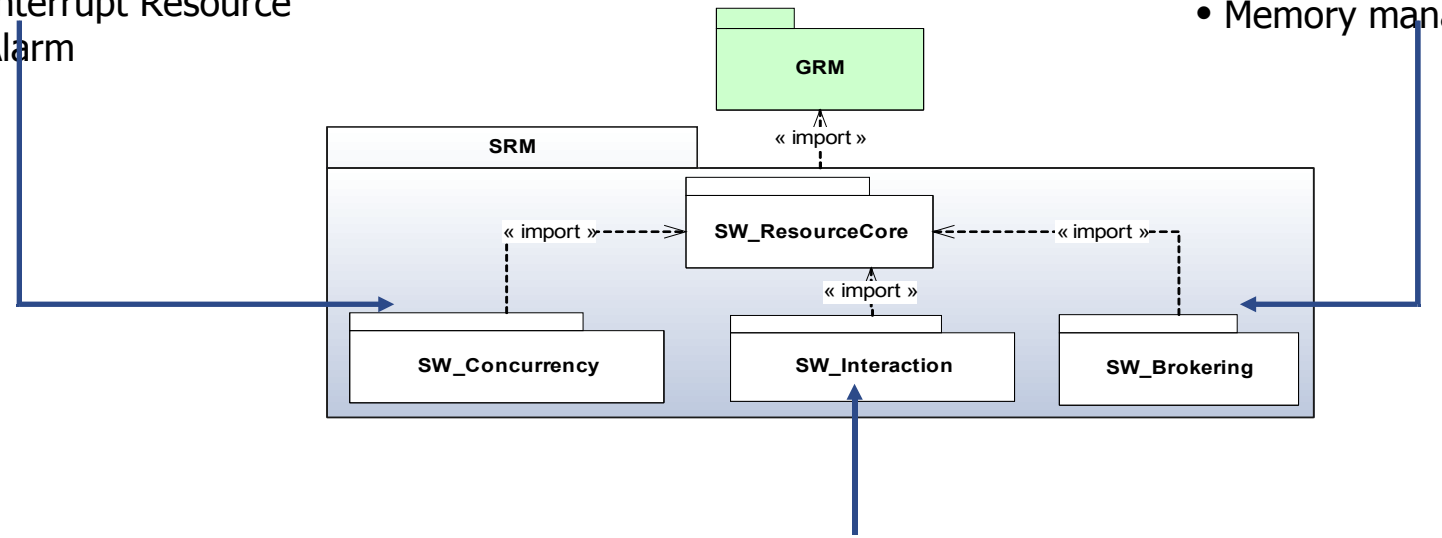
What is supported by the SRM profile ?

Concurrent execution contexts:

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

Hardware and software resources brokering:

- Drivers
- Memory management

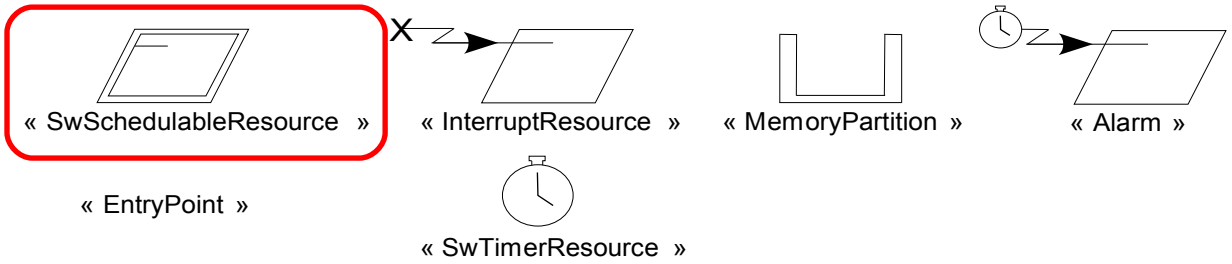


Interactions between concurrent contexts:

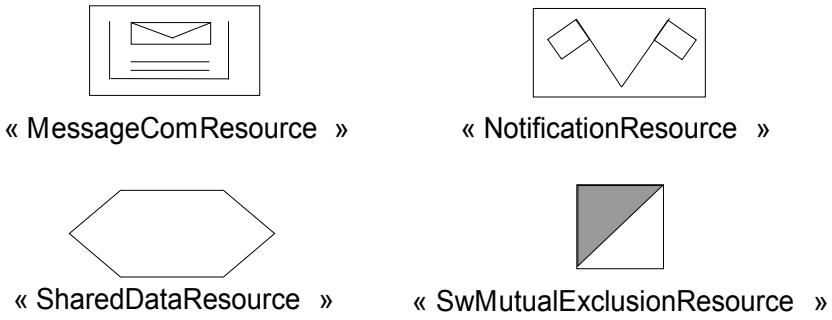
- Communication (Data exchange)
  - ✓ Shared data
  - ✓ Message (Message queue)
- Synchronization
  - ✓ Mutual Exclusion (Semaphore)
  - ✓ Notification (Event mechanism)

Overview of the UML extensions for SRM

SRM::SW_Concurrency



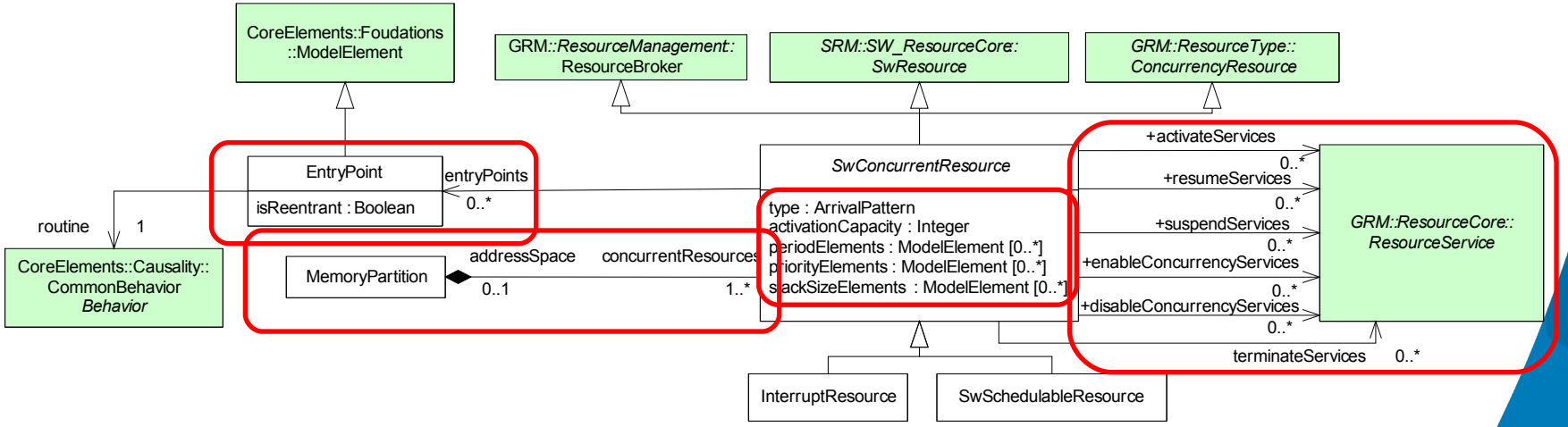
SRM::SW_Interaction



SRM::SW_Brokering

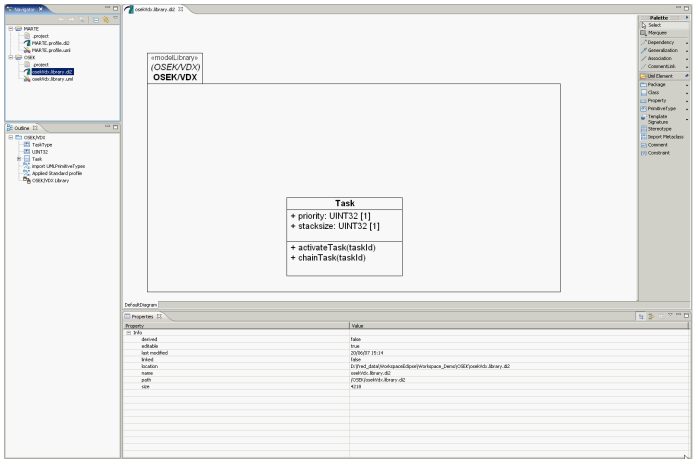
Details of the SRM::SwSchedulableResource stereotype

- SwSchedulableResource (from MARTE::SR::Concurrency package)
  - Semantic :
    - Resources which execute concurrently to other concurrent resource
    - Periodic or aperiodic
  - Main features
    - Owns an entry point
      - Code to execute in its execution context
    - May be restrict to a specific address space (i.e. a memory partition)
    - Owns properties : Priority, Deadline, Period, StackSize …
    - Provides services : Activate, Resume, Suspend …



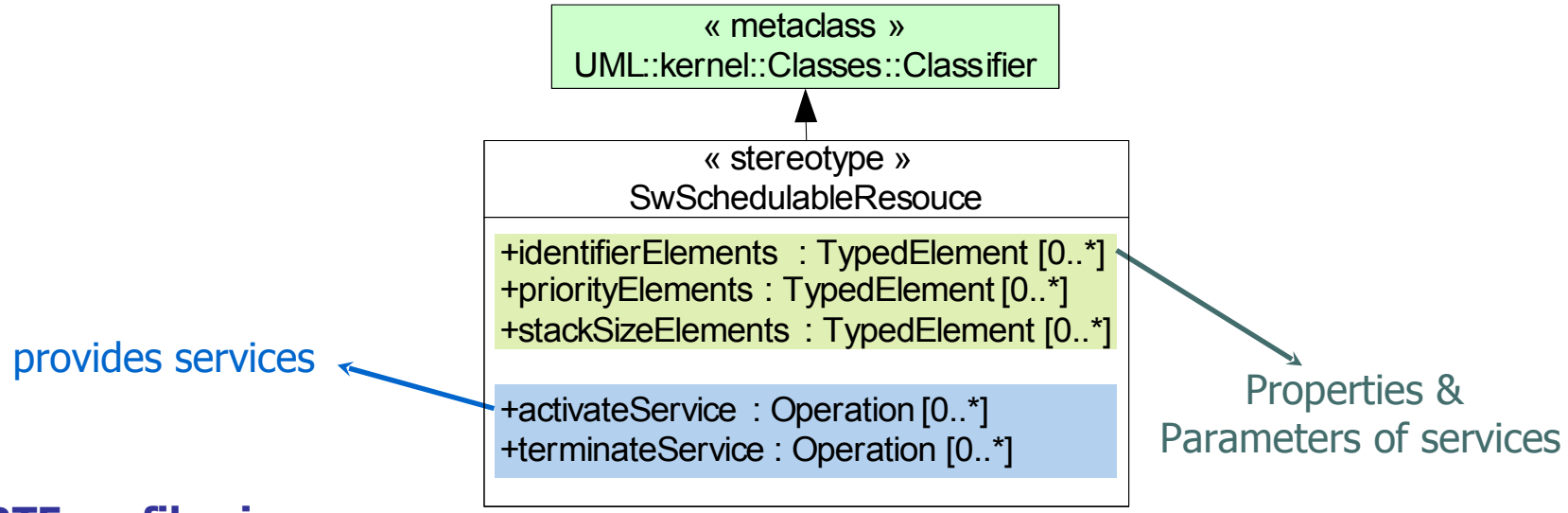
How to model the OSEK/VDX Task with SwSchedulableResource ?

- Describe the OSEK/VDX Task as a UML::Class of a OSEK/VDX model library
- Apply the SRM profile to the library
- Apply the « SwSchedulableResource » stereotype to the Task Class
- Fulfill the tagged values
  1. Reference the properties (i.e. attributes)
  3. Reference the services (i.e. operations)



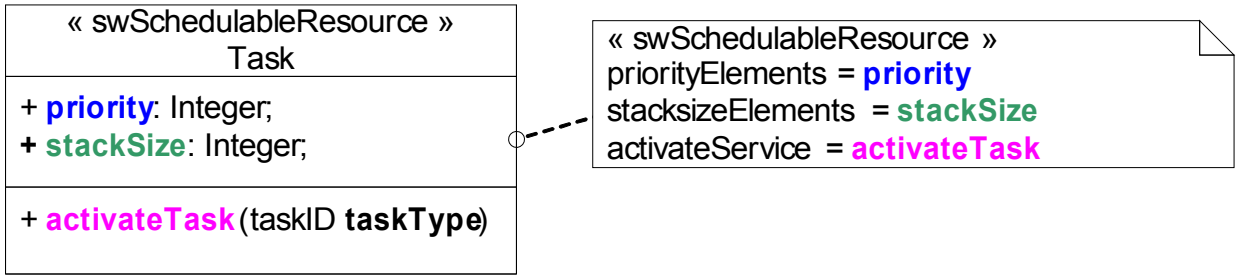
UML TOOL
http://www.papyrusuml.org

How to model the OSEK/VDX Task with SwSchedulableResource ?



MARTE profile view

User model view

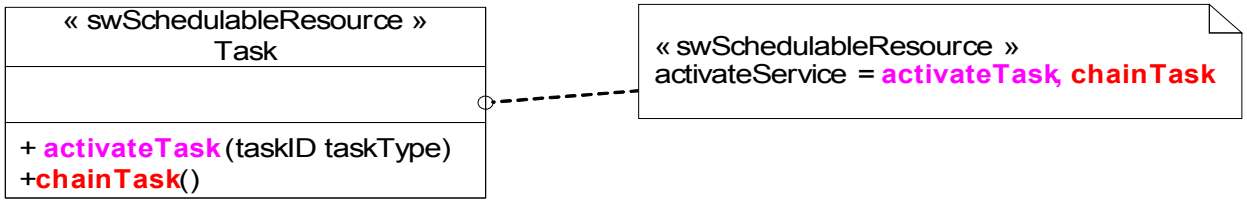


SRM modeling possibilities

- How to model multiples candidates for the same semantic ?
  - Answer : All stereotype tags have multiple multiplicities. Thus, it is possible to reference multiple candidates for the same tag.

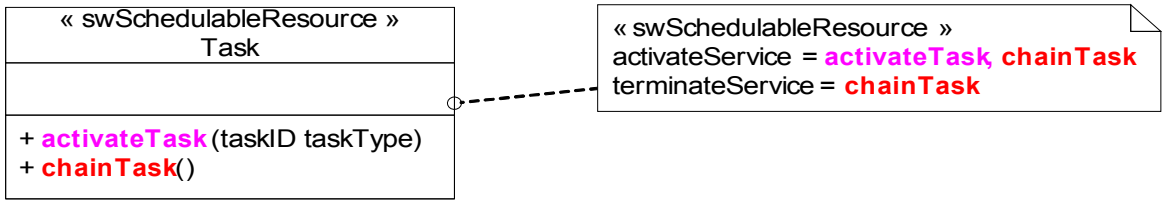
    - Examples
      - The name and the *taskId* own the same semantic : the task identifier

      - Both *activateTask* and *chainTask* services activate a task

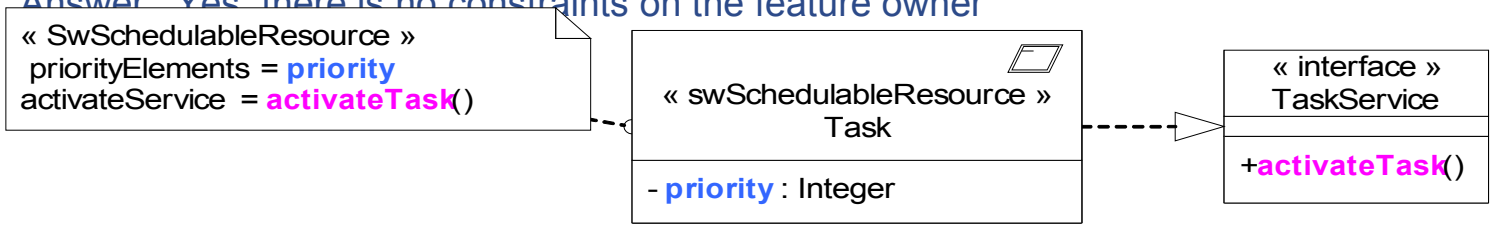


SRM modeling possibilities

- How to model a feature which have multiple semantic ?
  - Answer : Feature can be referenced by several tags
    - Example
      - The *chainTask* service terminate the calling task and activate the *<taskID>* one



- Is it possible to reference a feature even if the feature owner is not the stereotyped element ?
  - Answer : Yes, there is no constraints on the feature owner



- SRM allows multiple usages
  - User can use constraints, such as OCL rules, to limit those possibilities

OSEK/VDX OS Overview

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- Mechanisms :
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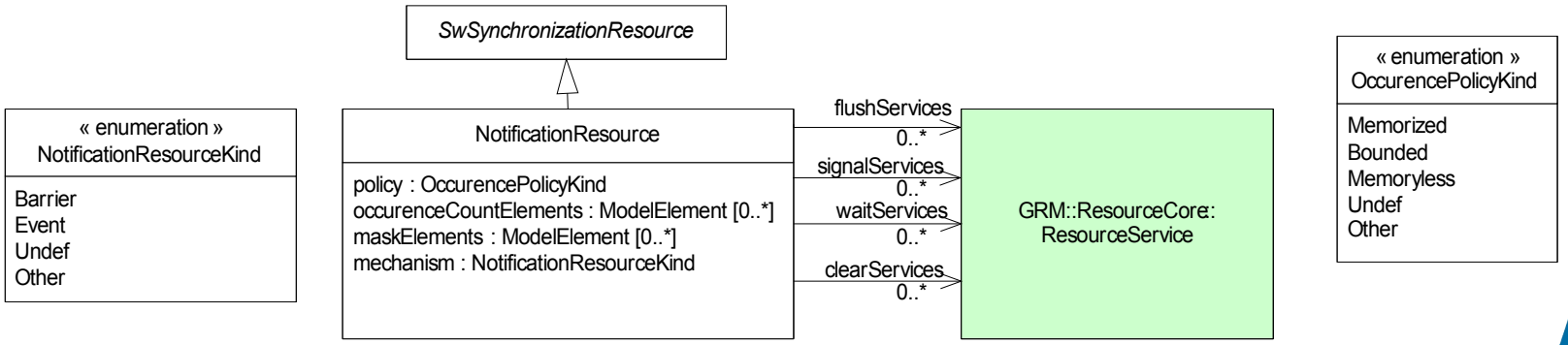
      - » Mechanim for mutual concurrent access exclusion

OSEK/VDX Event

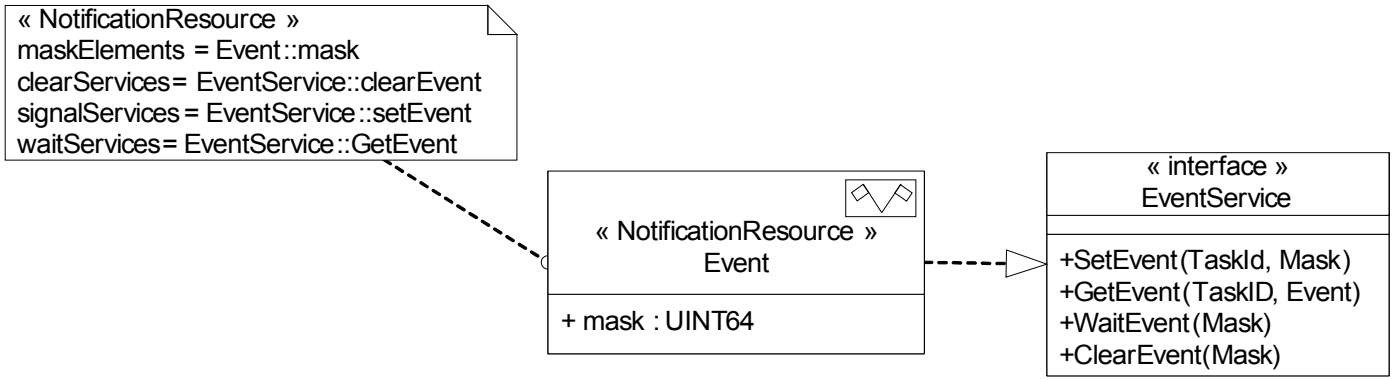
- Semantics:
  - The event mechanism
    - is a means of synchronisation
    - initiates state transitions of tasks to and from the *waiting* state.
  - Specific Properties :
    - **Mask :** EventMaskType
  - Specific Services :
    - **setEvent (TaskID, Mask)** : The events of task **<TaskID>** are set according to the event mask **<Mask>.** Calling **SetEvent** causes the task **<TaskID>** to be transferred to the ready state, if it was waiting for at least one of the events specified in **<Mask>.**
    - **waitEvent (Mask)** : The state of the calling task is set to *waiting*, unless at least one of the events specified in **<Mask>** has already been set.
    - **…**

OSEK/VDX Event as a NotificationResource

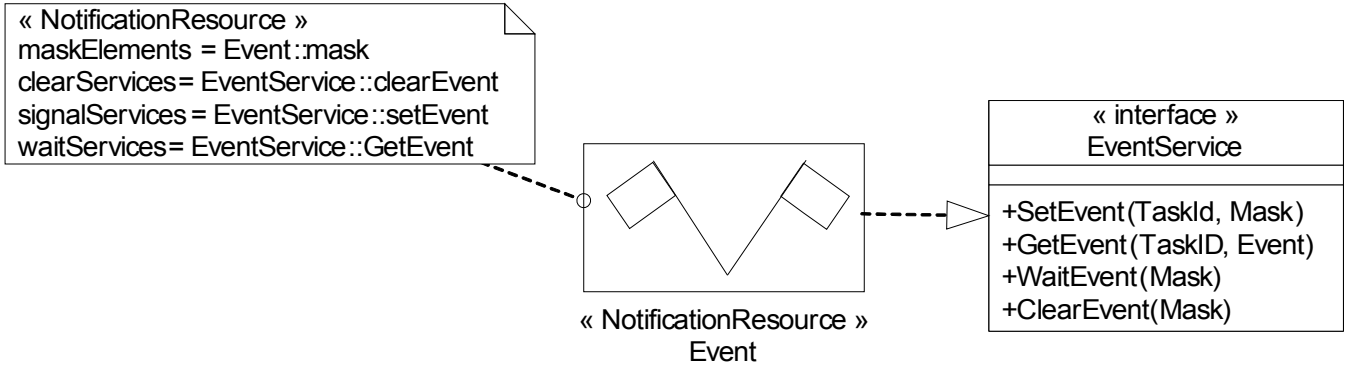
- NotificationResource
  - Semantic *:*
    - *NotificationResource supports control flow by notifying the occurrences of conditions to awaiting concurrent resources* Linked to an entry point (code to execute in its execution context)



OSEK/VDX Event as a NotificationResource

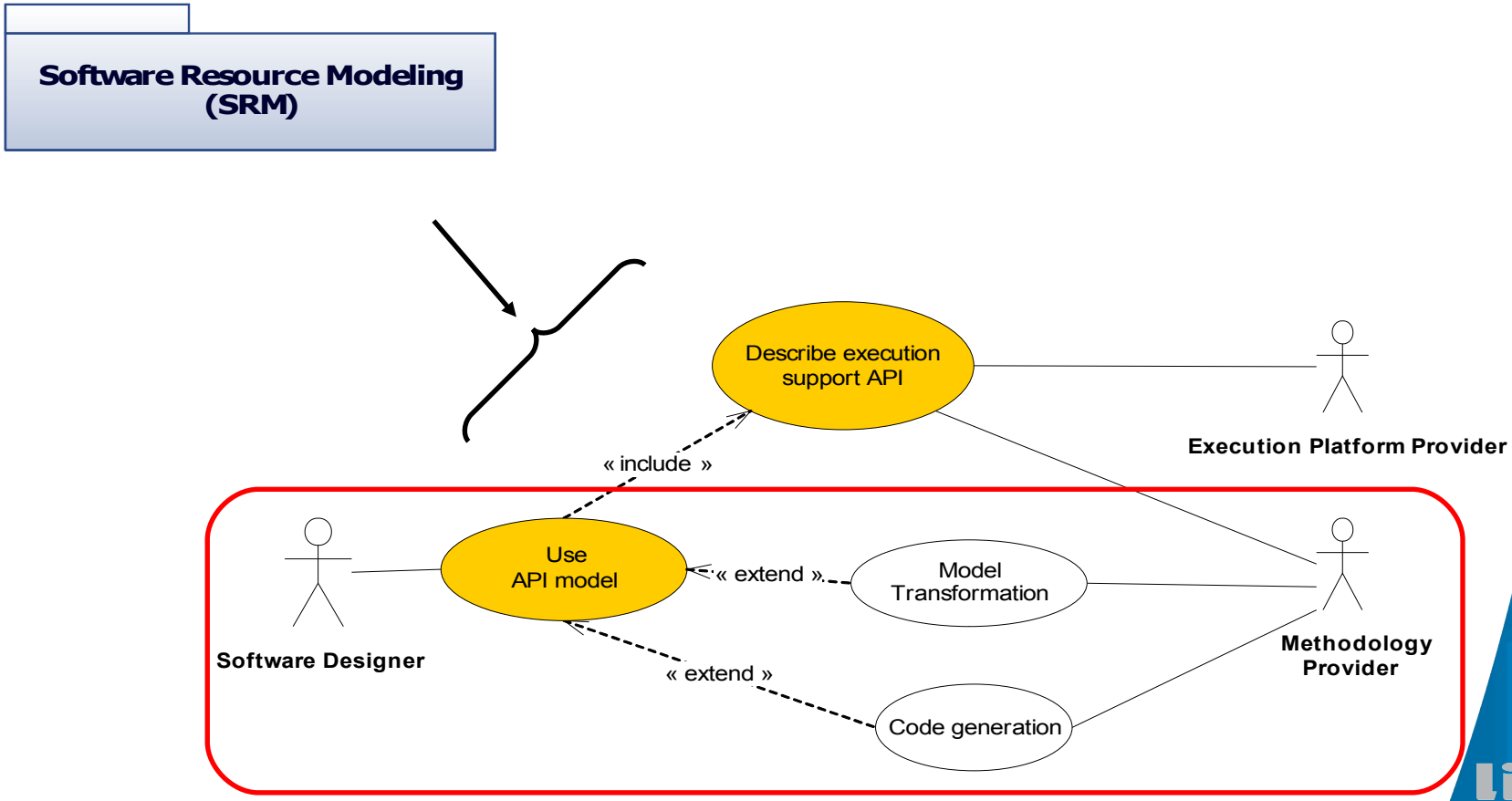


(i) Stereotype icon



(ii) Stereotype shape

In which typical cases shall I use SRM ?

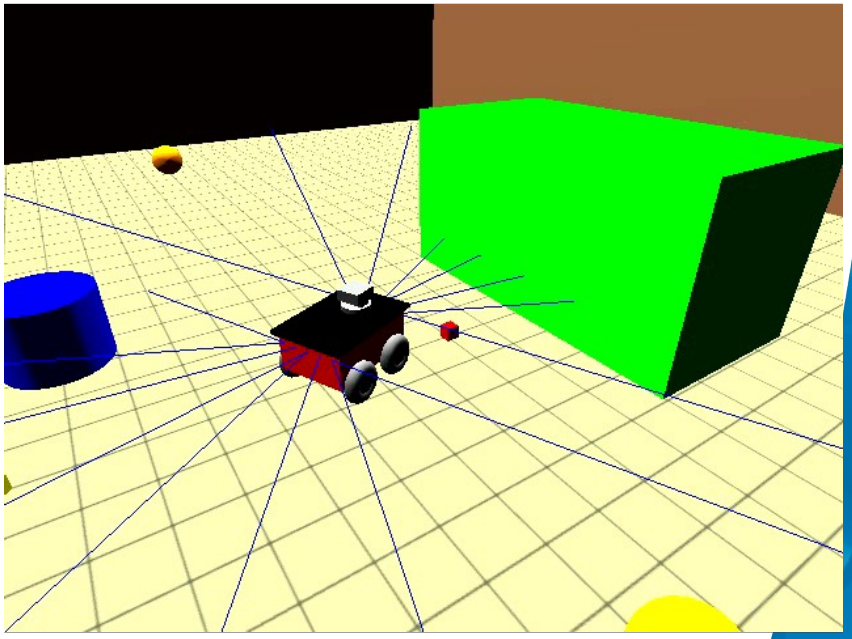


Examples of RTOS API model uses

- 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
- Example 3: Assistance to port applications
  - From OSEK to ARINC multitask design

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 …
- Controller features
  - Motion Controller
    - Two periodic tasks :
      - Acquisition : Get sonar sensors interfaces
        - » period =1 ms
      - trajectoryController : Set new speed
        - » period = 4 ms
    - OSEK/VDX execution support
      - Trampoline (http://trampoline.rts-software.org/)



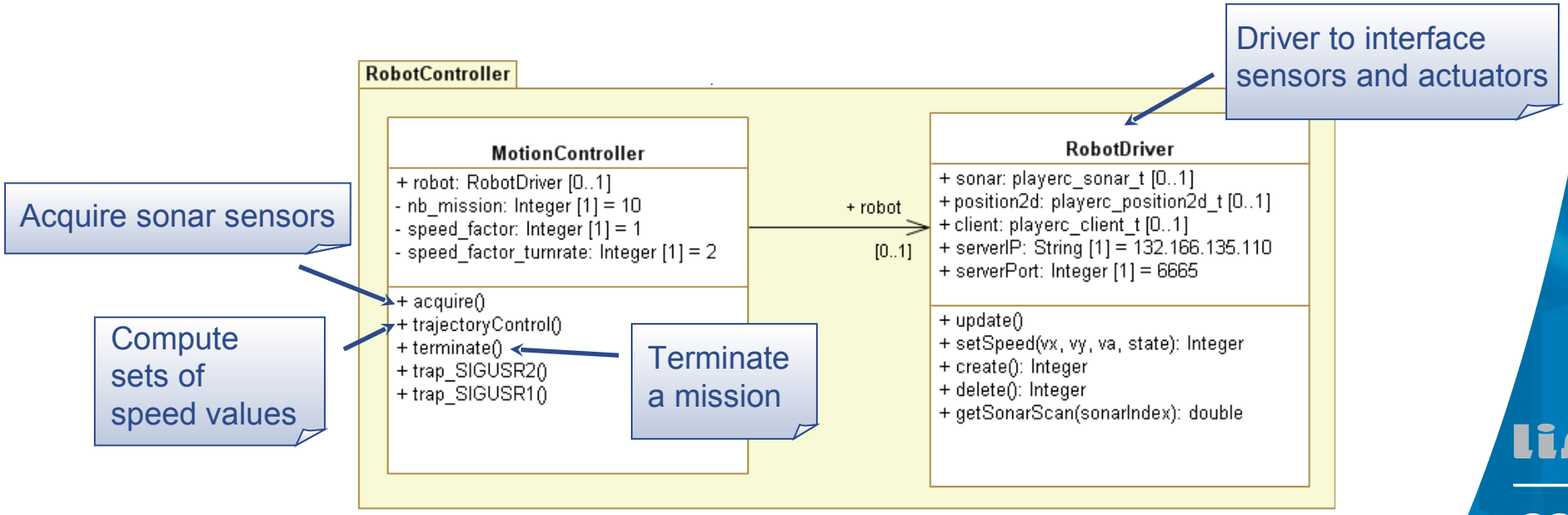
Robot Simulator
http://playerstage.sourceforge.net/gazebo/gazebo.html

Purpose

- Provide a multitask design of our robot controller
  - Multitask design must be based on the OSEK/VDX platform
- Design process
  - Platform Provider supplies the OSEK/VDX model library
    - model library is described with the SRM Profile (previous slides)
  - User designs a multitask model of the application
    - High level application description
      - Deduce tasks requirements
    - Multitask design
      - User instantiates model library classifiers to design the multitask application
    - Binding of the high level description with the multitask design

Application design

- A robot controller entity :
  - To control the robot motions
  - A multitask entity
    - Acquire the sonar
    - Compute and assign new speed order
- A robot driver : To interface robot sensors and actuators



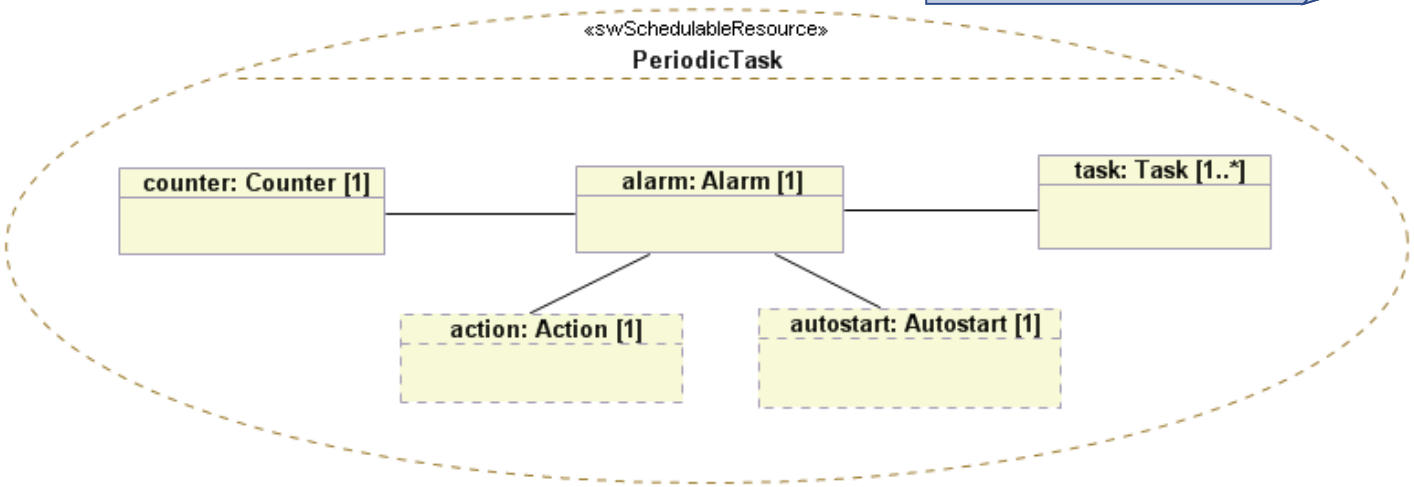
Basic multitask model

- Motion Controller
  - Two periodic tasks :
    - Acquisition :
      - Entry point : acquire() (Get sonar sensors interfaces)
      - Periodic
      - period =1 ms
    - trajectoryController
      - Entry point : trajectoryControl() (Compute and assign new speed order)
      - Periodic
      - period = 4 ms
- Robot driver
  - No tasks

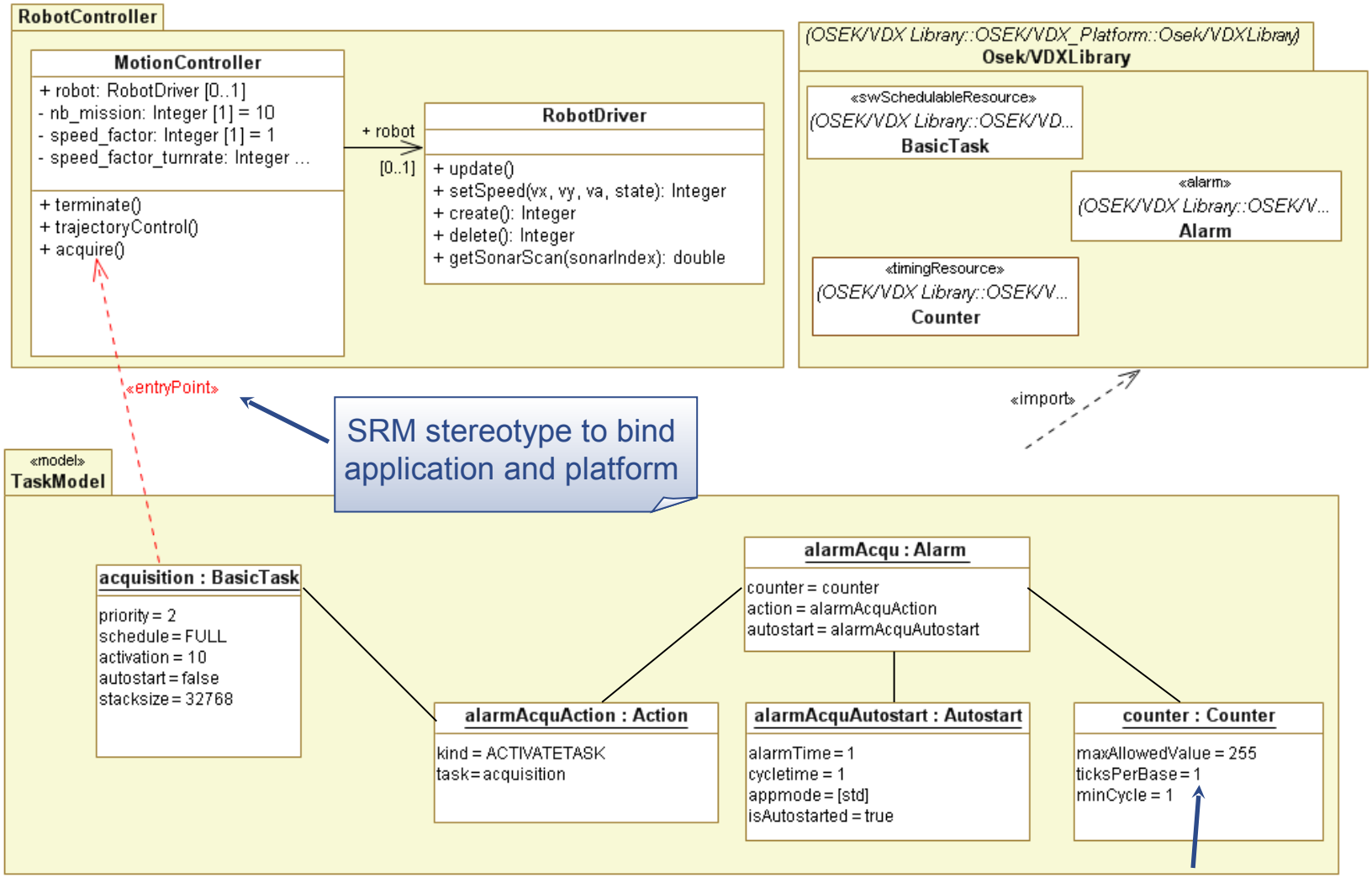
Periodic task in OSEK/VDX

- OSEK/VDX periodic task pattern
  - One OSEK/VDX Counter
    - Period : periodic task Period
  - One OSEK/VDX Task
    - Entry Point : periodic task Entry Point
  - One OSEK/VDX Alarm
    - AutoStart : Triggered by the counter
    - Action : Activate the task

SRM Profile is used to describe the pattern



Basic Robot Controller task models



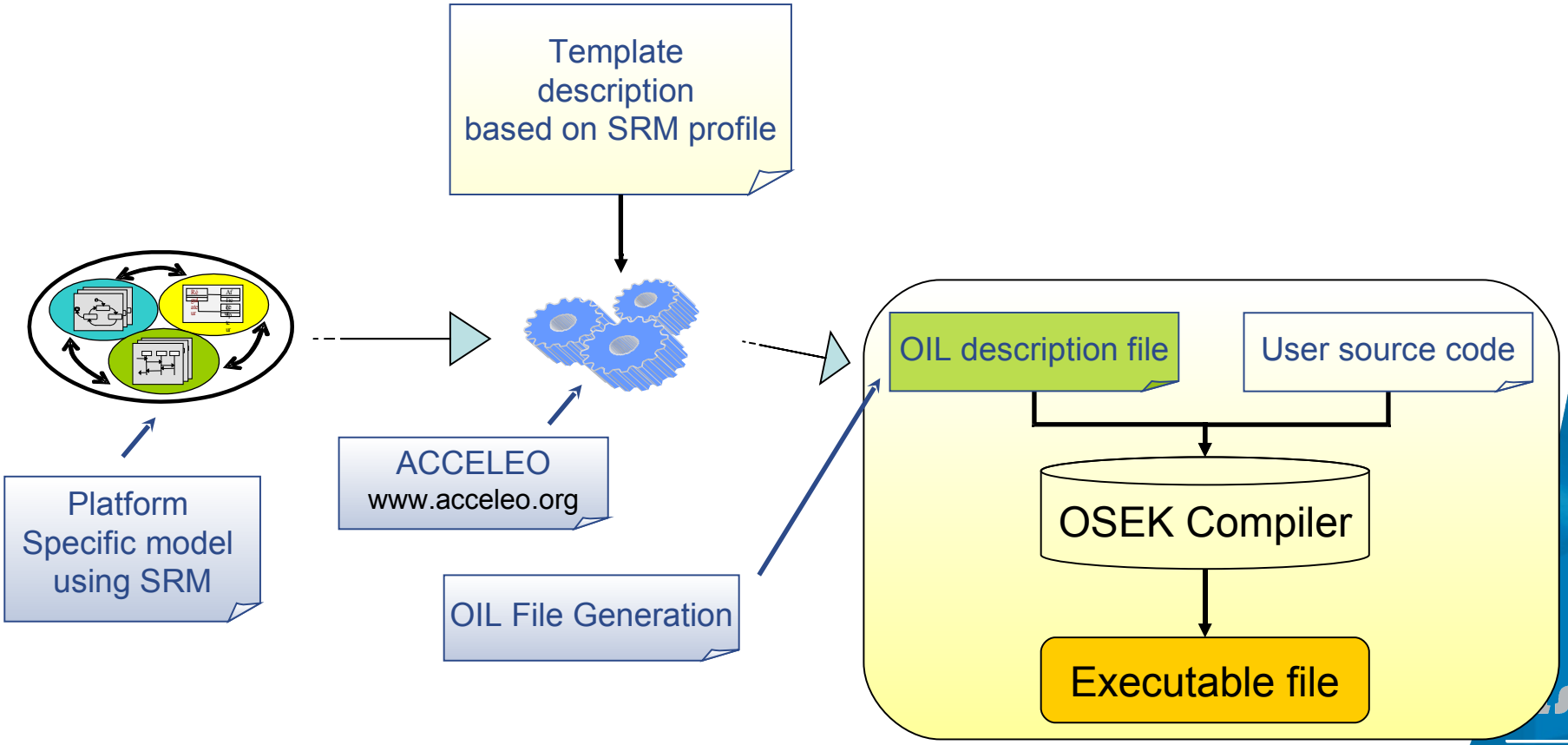
Use case : OSEK Configuration File generation

- Purpose
  - Generate 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 inside 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

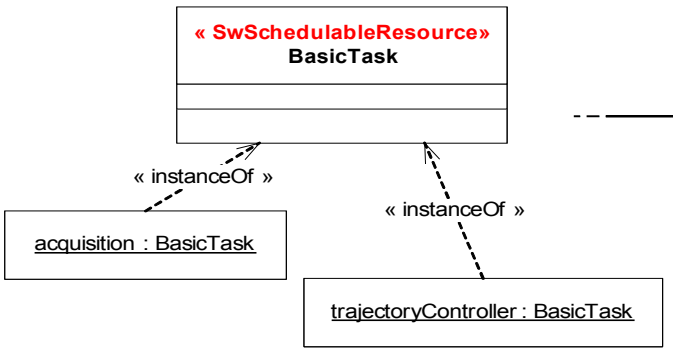
```
OIL_VERSION = "2.5" : "RobotController" ;

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 ;
  };
...
```

Principle to generate from a UML model an OIL description file



OIL template examples

```
For each UML InstanceSpecification {
        if its classifier has the SRM SwSchedulableResource stereotype then {
                generateText {
                        Task <Instance Name>{}
                }endGenerate
        }endif
}
```



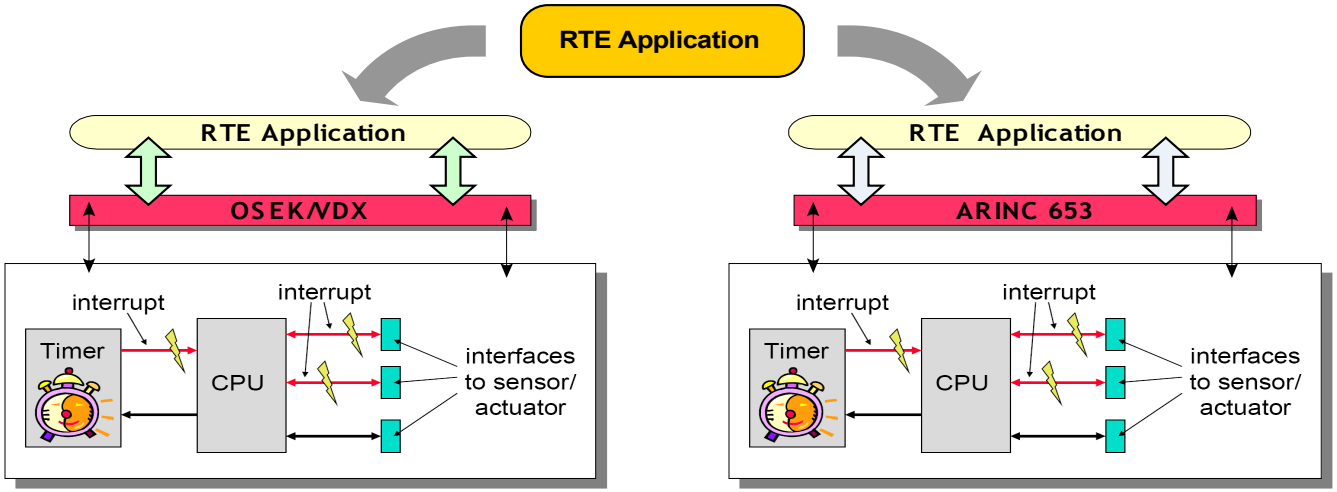
ACCELEO

```
Task acquisition{
}

Task trajectoryController{
}
```

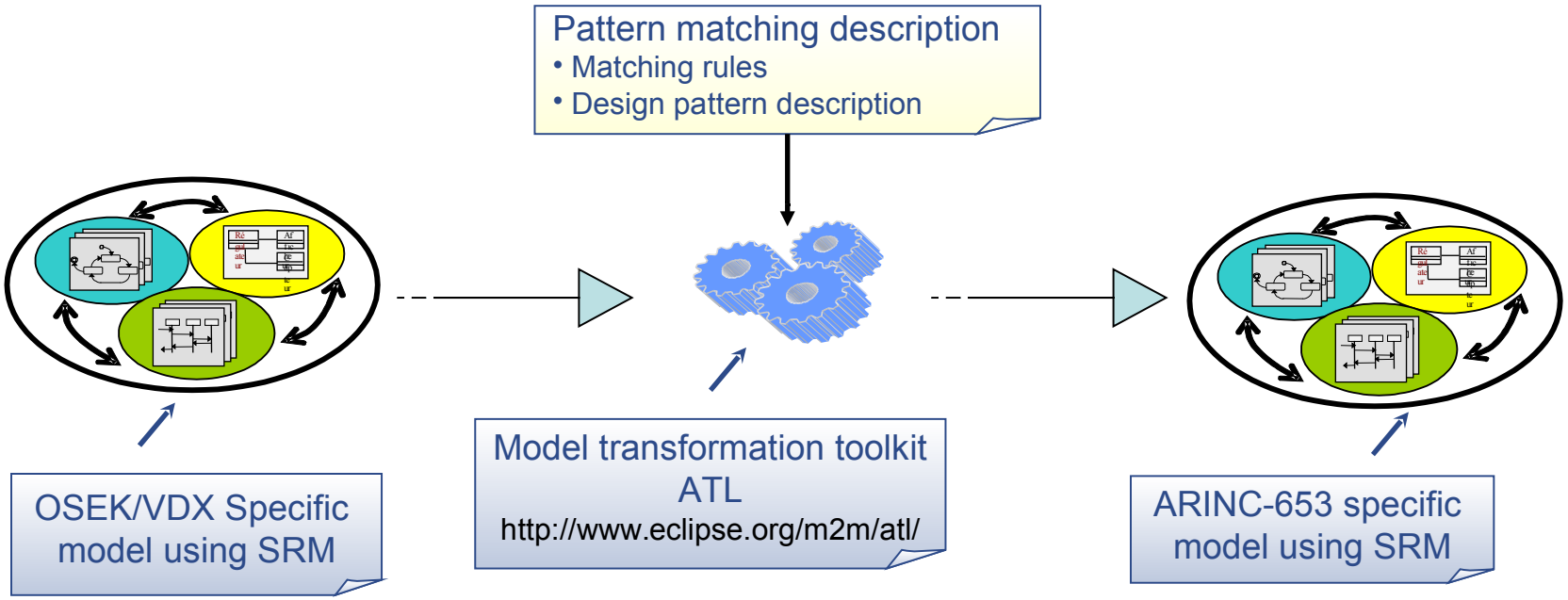
Generation of the OIL file in the Papyrus UML Tool

Example 3 : Assist user to port multitask designs

- Purpose:
  - Assist user to port the multitask design to an ARINC-653 RTOS
    - ARINC 653 standard provides avionics application software with the set of basic services to access the operating system and other system-specific resources.



Assist user to port multitask designs

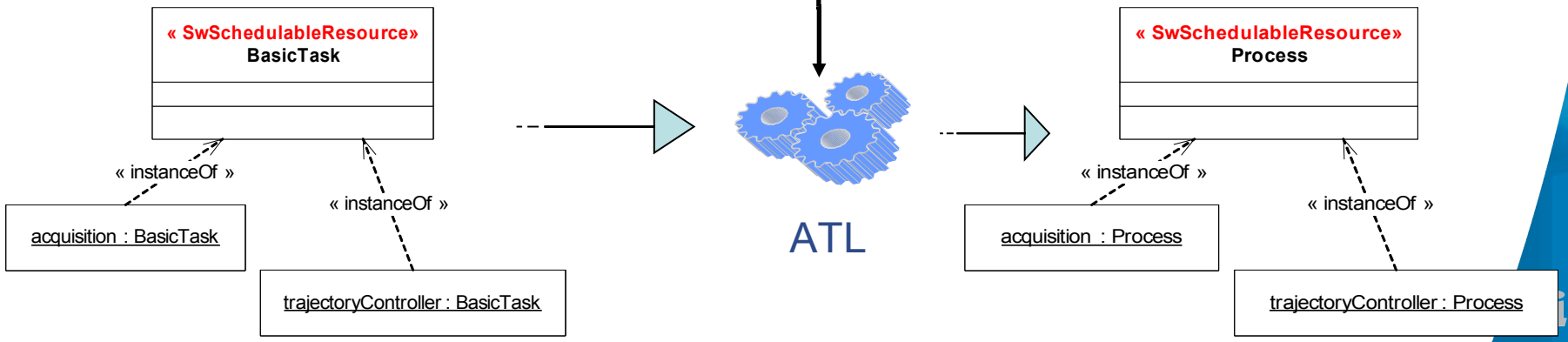


Matching pattern example (1/2)

For each UML InstanceSpecification {
if its classifier has the SRM SwSchedulableResource stereotype then {
- generate a new Instance Specification;
- its target classifier is that which is stereotyped

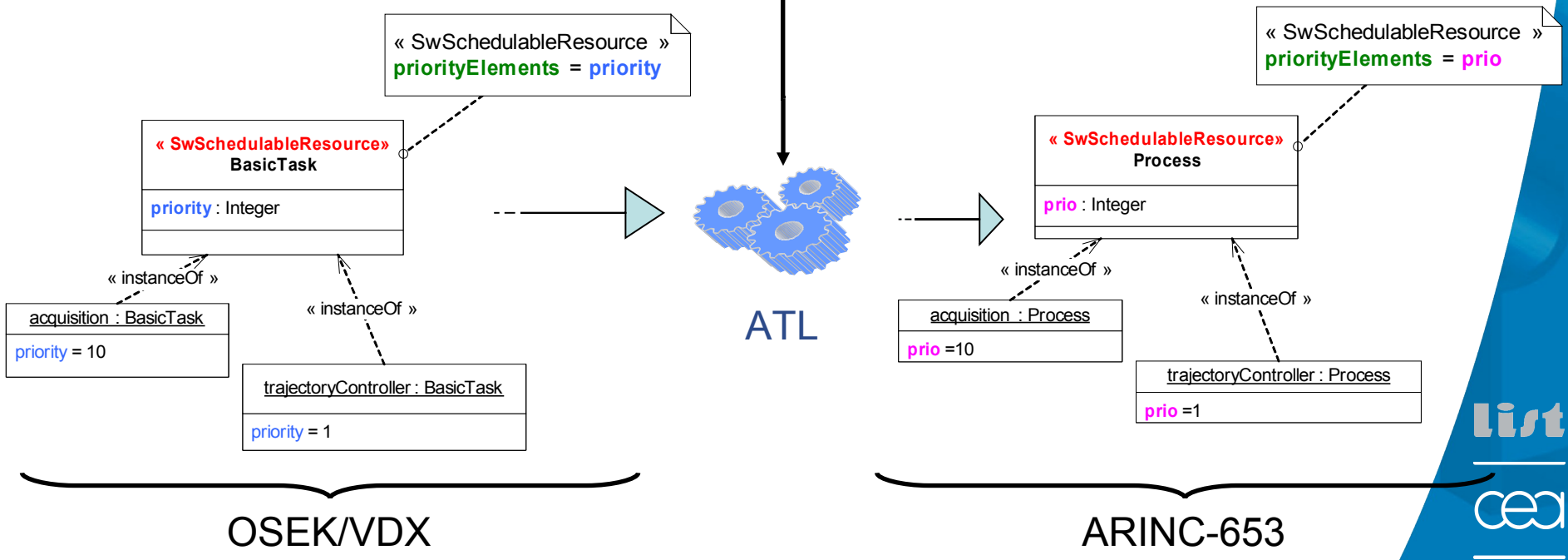
SwSchedulableResource in the target execution support;

}endGenerate
}endif
}



Matching pattern example (2/2)

For each UML InstanceSpecification {
if its classifier has the SRM SwSchedulableResource stereotype then {
- …
- each source priorityElements match one target priorityElements
}endGenerate
}endif
}



Assist user to port multi-task designs in the Papyrus UML tool : a basic example

Related resources

- The official MARTE web site: www.omgmarte.org
  - Tutorials, events, projects related and tools
- www.papyrusuml.org
  - On open source Eclipse plug-in for UML2 graphical modeling
  - MARTE implementation available within the V1.9 release of the tool