RobMoSys

Model-Driven Software Engineering in Robotics
Models, Tools, Systems, Solutions, Challenges

Tutorial at ACM / IEEE

22nd Int. Conf. On Model Driven Engineering Languages and Systems (MODELS)

www.servicerobotik-ulm.de/models2019

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cea

Hochschule Ulm
University of Applied Sciences

KU LEUVEN

TECHNISCHE UNIVERSITÄT MÜNCHEN

COMAU

PAL ROBOTICS

SIEMENS

EUnited Robotics
European Robotics Association

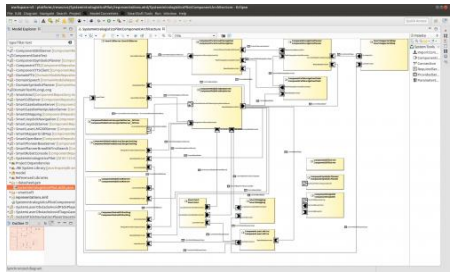
eclipse

What is this tutorial about?

- a major goal of this tutorial is to give the model-driven approaches of RobMoSys exposition in the “generic” MDE community. The aim is to foster a closer interaction between the MODELS community and the robotics model-driven software engineering community.
- for this, the tutorial provides insights into the current state-of-the-art of model-driven software engineering for robotics and according tools as driven by the robotics domain and consolidated via RobMoSys. It is also about explicating the special needs of robotics and discussing these with the MDE community.

What are the benefits for participants?

- see how models / MDSD / SWE and Pilot Applications converge in the domain of robotics as moderated by RobMoSys
- get the links to our technical material such that you can go into deep details of how we organize models, tools, systems for robotics and get aware that we would like to see contributions from the MODELS community
- get introduced into and guided through our Eclipse-based toolings for robotics such that you can try out the next steps on your own



To get a quick overview on the audience

RobMoSys

where do you come from?

- industry?
- academia?
- …?

what is your application domain?

- robotics?
- automotive?
- IoT / I4.0?
- no specific one
- …?

what is your expertise?

- foundations of (meta-)modeling, model processing, …?
- model-driven tools, code generation, ...?
- software engineering, code excellence, …?
- …?

what is your link to RobMoSys?

- already involved
- heard about it or know it and want to know more
- do not know anything yet but tutorial sounds interesting

Getting involved into RobMoSys

RobMoSys

www.robmosys.eu

RobMoSys

Third Party Funding Opportunities

Composable Models and Software for Robotics Systems

RobMoSys's main goal is to create and consolidate an EU Digital Industrial Platform for Robotics to establish a common methodology for model-based software development. In doing so, we will improve tools and foster interoperability by model interchange and composability. The Open Calls for contributions to RobMoSys is one of the means implemented to achieve this goal.

CALL BASICS

Call identifier: RobMoSys-SROC
Call title: Second RobMoSys Open Call
Total budget: €475.000
Submission language: English
Call Opening: 1st August 2019
Call Deadline: 31st October 2019

CALL 2 - 2nd cut-off

Calling for 2 different Instruments
Expected duration and maximum funding request per proposal: see below
Optional **pre-proposal check**
Submission platform:
opencalls.robmosys.eu/all_calls

FACTS & FIGURES

Instrument	# 1: Fast Adoption	# 3: Innovation Expert Intake
Call for	proposals	proposals
Runtime	6 months	6 months
Total indicative budget	€360.000	€100.000
Funding per proposal	€60.000	€20.000 (Maximum)
Pre-proposal deadline	30th September	30th September
Call Deadline	31st October	31st October

FOCUS OF CALL 2

Industry-Driven Ecosystem.
RobMoSys defines a model-based ecosystem of assets and services to help the robotics industry improve their software/system engineering practice.
We are looking for proposals joining us in our effort to create this ecosystem and to demonstrate your success story with real industrial use cases.

Towards a Strong RobMoSys Community.
We call for expert groups willing to be coached by members of the RobMoSys core consortium in order to implement the RobMoSys concepts. Successful applicants must be ready to advance the RobMoSys way of thinking, and to go for real world examples in line with the RobMoSys industrial pilots (developed by the RobMoSys core consortium).

WHAT WE ARE CALLING FOR

The second cut-off of the second call for proposals in RobMoSys embraces 2 different ***Instruments***. A instrument is a type of RobMoSys third-party contract characterized by a profile of contributions, a funding scheme, distinctive expected results and hence different evaluation criteria

#1 FAST ADOPTION

RobMoSys wants to boost a **fast adoption** of the RobMoSys approach in industry. This Instrument focuses on **SMEs** and **small teams in large industrial companies**, target groups ranging from **software component suppliers** to **robotics system builders**.

The funded projects must develop RobMoSys-conformant pilots (**industrial case studies**) based on existing assets (software and tools from the RobMoSys ecosystem), or provide software components conformant to the RobMoSys pilots.

ITPs funded are not expected to build applications with fully RobMoSys-conformant software components. At least two of these RobMoSys-conformant components have to be implemented, though.

#3 INNOVATION EXPERT INTAKE

We are looking for proposals from legal entities offering **expert services** in order to push innovation and strengthen the RobMoSys **community**.

Applications can focus on **supporting the RobMoSys Academy** or the RobMoSys **technology**.

Herewith, experts must be willing to familiarize themselves with the RobMoSys approach, actively participate in technical workshops, meet with RobMoSys partners in their labs, contribute to the RobMoSys community building, or get involved in specific ITP (Integrated Technical project).

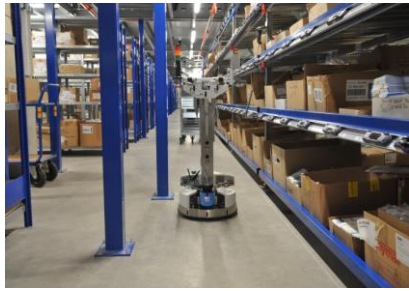
Experts with the following background could make a valuable contribution to the RobMoSys project:

- experts solely involved in the ROS-ecosystem so far, but wanting to get actively involved in RobMoSys now
- experts in real-time embedded systems willing to link their concepts to RobMoSys
- deep software engineering experts wanting to identify how to overcome deficiencies in model-driven tooling workbenches
- experts in automotive software engineering wanting to push forward a link to their resource management

Applicants with other expertise relevant for RobMoSys are also welcome.

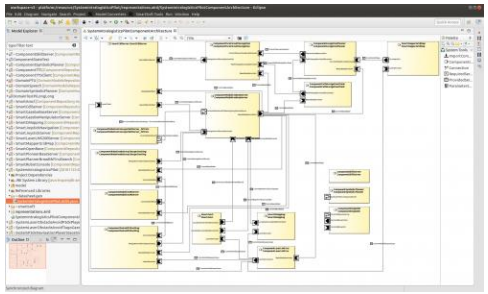
Getting involved into RobMoSys

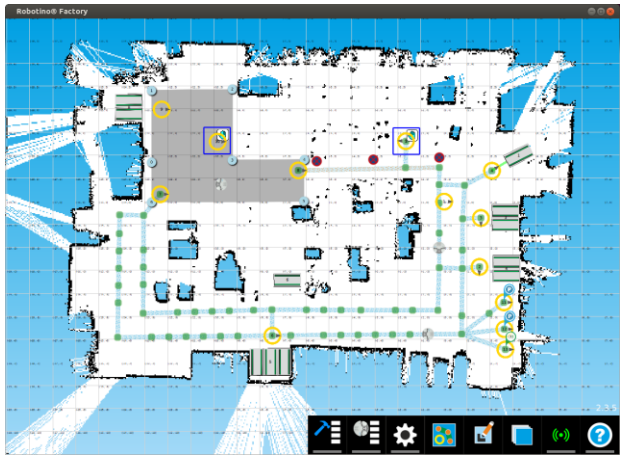
- http://robmosys.eu/wiki/
- https://robmosys.eu/wiki/open-call-2
- https://robmosys.eu/wiki/model-directory:start
- https://discourse.robmosys.eu/
- https://robmosys.eu/wiki/pilots:start

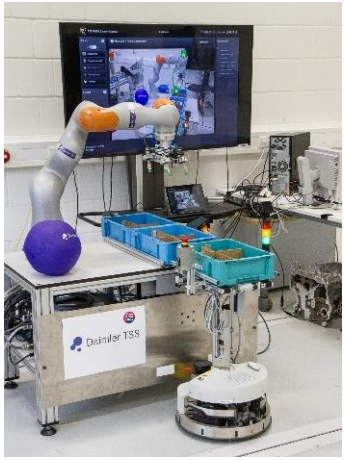


https://www.youtube.com/user/RoboticsAtHsUlm/videos

Service Robotics Ulm
autonomous mobile service robots







“Behind of what you see at the surface of RobMoSys, there is a much broader body of knowledge that is definitely worth spending the effort of going into it.”

Matteo Matteucci (Politecnico di Milano)

RobMoSys

There is something under the hood that made me become an ambassador of RobMoSys

“Don’t be confused about meta- and meta-meta (...) models. There is something under the hood that generates a real value to its users. That has made me become an ambassador of RobMoSys.”

Davide Faconti (EURECAT Technology Centre of Catalonia)

RobMoSys is beyond the limitations of most software approaches used in robotics

"The methodology of RobMoSys allows to improve how we build and assemble systems with components. This goes beyond the limitations of most software middleware used in robotics, which gives little support to help integrators figuring out how to combine components effectively."

Lorenzo Natale (Instituto Italiano di Tecnologia, IIT)

I am impressed with the maturity of tools and I feel at home in RobMoSys

“I am quite impressed with the maturity of the RobMoSys tools [here: SmartMDSD Toolchain]. I can recommend it to grasp the practical consequences of RobMoSys and apply the concepts in an effective way. Even in the first steps, you will understand the power of the approach and how you can gain from the RobMoSys benefits: It makes the composition of systems easier and I see the benefit of separation of roles. I feel at home in RobMoSys now.”

Bouke Krom (Netherlands Organization for Applied Scientific Research TNO)

https://robmosys.eu/testimonials/

Schedule

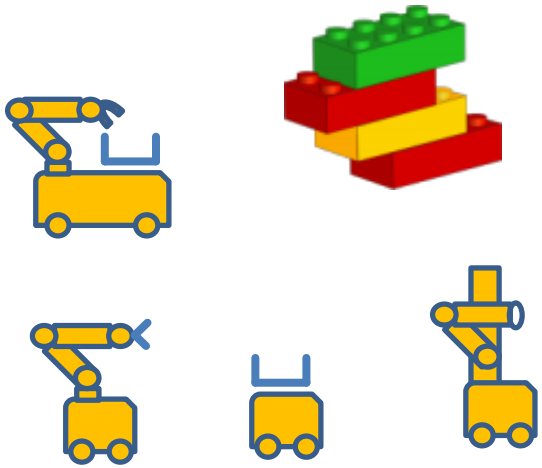
RobMoSys

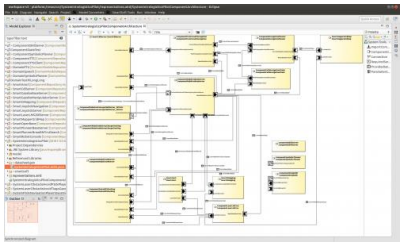
09:00 – 09:30	*(25+5 min)*	Introduction to RobMoSys and how to get access into RobMoSys Christian Schlegel, Technische Hochschule Ulm
09:30 – 10:10	*(40 min)*	Interactive Tool Demo: Piecing together software components to robotics pilot applications Alex Lotz, Dennis Stampfer, Technische Hochschule Ulm
10:10 – 10:30	*(20 min)*	Part 1 of Interactive Tool Demo: Stepwise Migration to Model-Driven Development Alex Lotz, Dennis Stampfer, Technische Hochschule Ulm
10:30 – 11:00		**Coffee Break**
11:00 – 11:20	*(20 min)*	Part 2 of Interactive Tool Demo: Stepwise Migration to Model-Driven Development Alex Lotz, Dennis Stampfer, Technische Hochschule Ulm
11:20 – 12:00	*(40 min)*	Safety-analysis by model-driven tooling Huascar Espinoza, CEA List
12:00 – 12:30	*(30min)*	The Role of Higher-order Models in Robotics and its Reasoning Challenges Herman Bruyninckx, KU Leuven

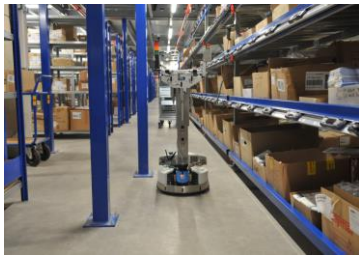
Towards an EU Digital Industrial Platform for Robotics…

RobMoSys

…unlocking the potential of robotics
…unlocking new business opportunities
…unlocking the power of a robotics ecosystem

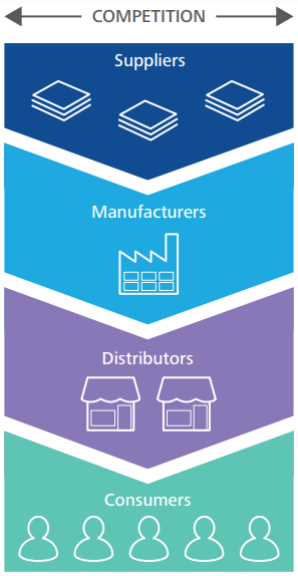






Towards an EU Digital Industrial Platform for Robotics…

- The world is entering an era in which ideas and insights come from everywhere, and crowds, clouds, collaborators, competitions, and co-creators can fundamentally help define our shared future. The business environment is being permanently altered as a result.
- Ecosystems are dynamic and co-evolving communities of diverse actors who create and capture new value through both collaboration and competition.



Business ecosystems come of age, Deloitte University Press, 2015

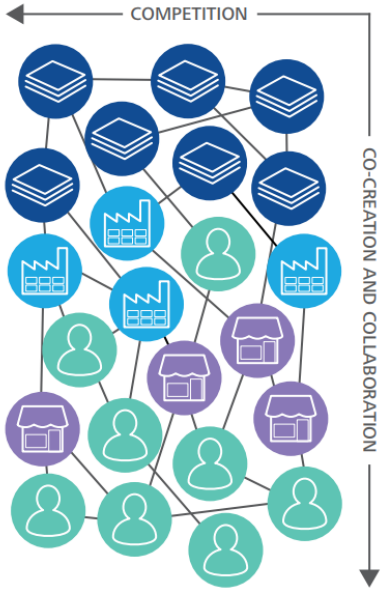
changeability / flexibility of robotics not yet economically exploitable to face pressure of lot size 1

robots are not yet a tool which I can adjust myself to match my daily changing needs

in robotics, costs of change are not proportional to similarity of solution

expectations of many domains to use robots cannot be fulfilled due to too high effort / costs

...



For the most part, supply chain functions of large businesses weren't set up to deal with a world of thousands of partners. Now they must adjust.

A distinctive characteristic of many ecosystems is that they form to achieve something together that lies beyond the effective scope and capabilities of any individual actor (or even group of broadly similar actors).

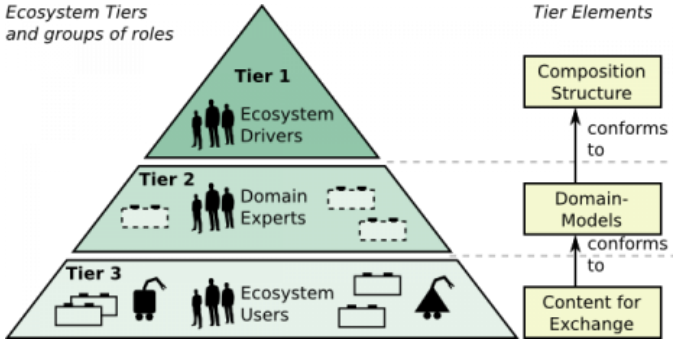
Core Approach: Blocks, Ports, Connectors

RobMoSys

Separation of roles

Building blocks with digital data sheets

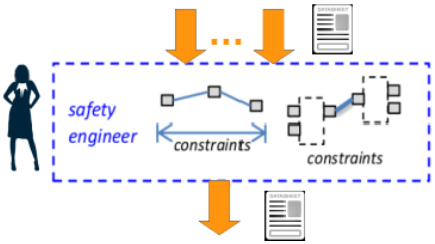
Model-driven composition
Coverage, conformance, interoperability, diversity
Community body-of-knowledge by models

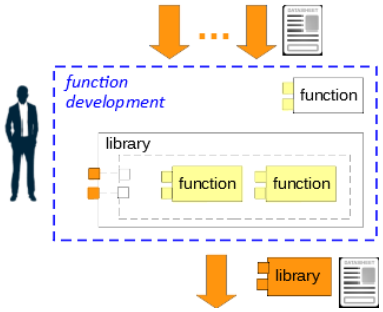


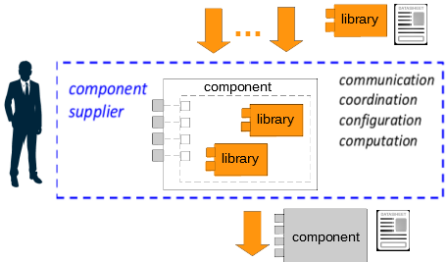
Tier 1 content:
Modeling Foundations & Composition Structures

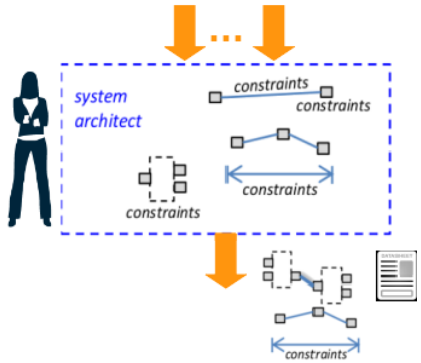
Tier 2 content:
Domain Models & Stacks

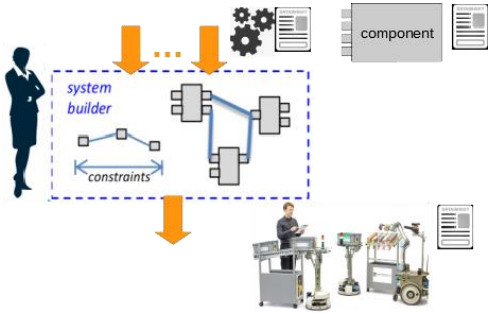
Tier 3 content:
Components & Systems











- Methodology
- Meta Models
- Models
- Implementation Technologies
- Toolings
- Building Blocks
- Pilot Applications
- Repositories

Toolings: achieve better quality with less effort

RobMoSys

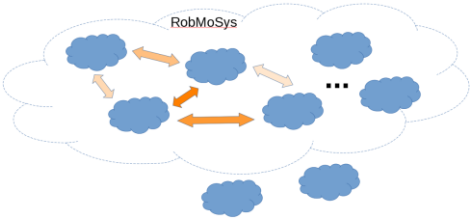
SmartMDSD Toolchain

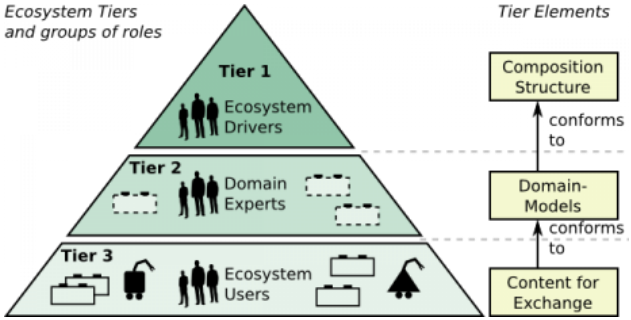
- RobMoSys Plugins
- SeRoNet Plugins
- OPC UA Plugins
- Middleware Plugins
- ... Plugins

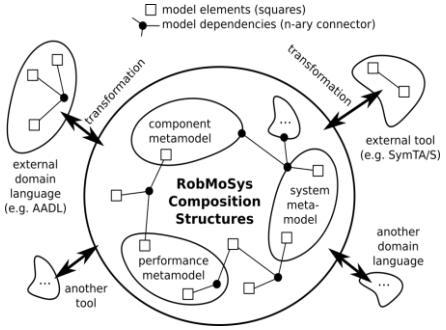
modeling Sirius

#ROBOTICS

eITUS
Safety View for Papyrus4Robotics







RoQME
Plugins for the SmartMDSD Toolchain

EG-IPC
Meta-Models
Models

CARVE
YARP Mixed Port Component with SmartMDSD

Plug & Bench
Benchmark Engineering Tool for Skill Level, links with SmartMDSD

Mood2Be
BehaviorTree.CPP: Execution engine for behavior trees

Mood2Be
Groot, an IDE to create, modify and monitor BehaviorTrees

https://robmosys.eu/wiki/baseline:start

Digital Data Sheets: What you need to know…

RobMoSys

https://wiki.servicerobotik-ulm.de/academy:datasheet

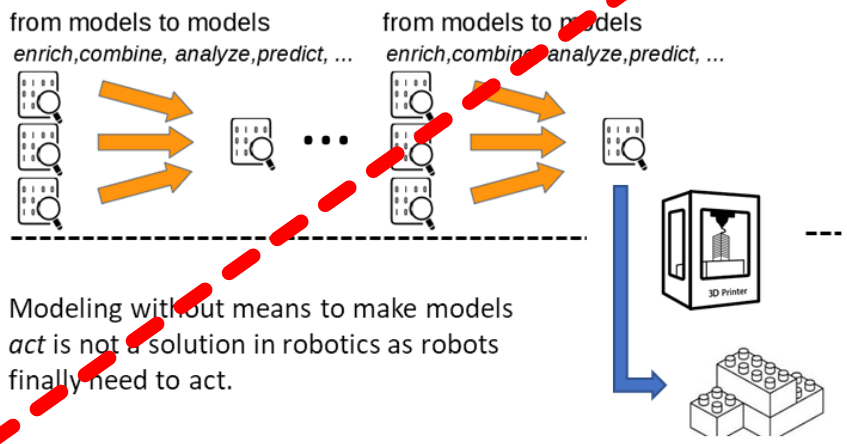
Digital Data Sheets…

…are ***models*** to enable an ecosystem

…ensure decoupled activities within an ecosystem

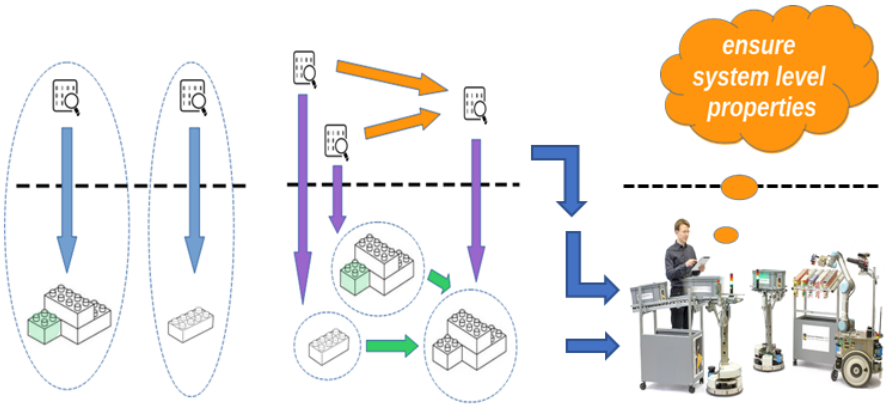
…allow selection, predicition, what-if-analysis and more

Composing different models for a full-fledged model for synthesis as the last step in the workflow so far only works in selected use-cases of 3D-printing.



Modeling without means to make models *act* is not a solution in robotics as robots finally need to act.

Data sheets (models of artefacs that act) *represent* components, sub-systems, task-plots etc. Suitability, traceability, simulation, etc. of system properties all via *composed data sheets*. When all is fine, then *compose* (put together and accordingly configure) the real artefacts to get the real system with properties as expected.

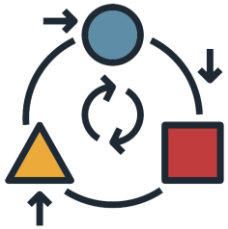


Digital Data Sheets: Industry 4.0 Asset Administration Shell

RobMoSys

- Brokerage Platform
- Online marketplace

- Component selection
- Component composition
- Component configuration



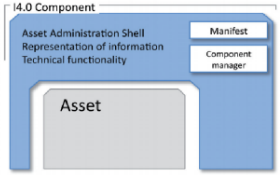
- Runtime adaptation
- Context awareness
- Robustness and self-X

RobMoSys

conformant to RobMoSys

Software Building Block (e.g. Component)

Software Artefact — represents — Digital Data Sheet



compatible to industry 4.0 asset administration shell

Software Building Block (e.g. Component)

SeRoNet | ROS

RobMoSys Ports

SmartSoft Ports | Plain OPC UA Ports (unstrukturiert) | Plain OPC UA Ports (strukturiert, z.B. Companion Spec.) | ROS Topics

RobMoSys System

Software Building Block (e.g. Component)

Descriptive Part: Manual annotations

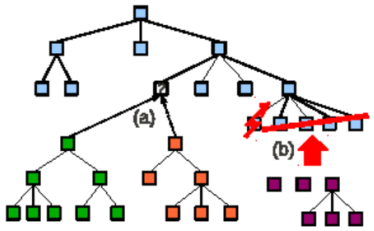
Semantic modeling, focus on **searching and selection**:
- Application domain
- Performance attributes
- Common speech in domain
- Restrictions

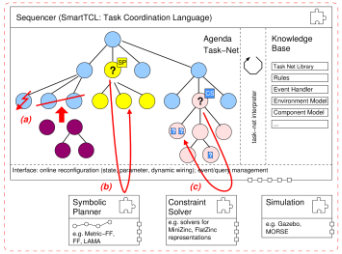
Technical Part: Generated from Models

Technical modeling, focus on **composition**:
- Component Model,
- Communication Patterns
- Variation Points
- Resource Constraints

Models…

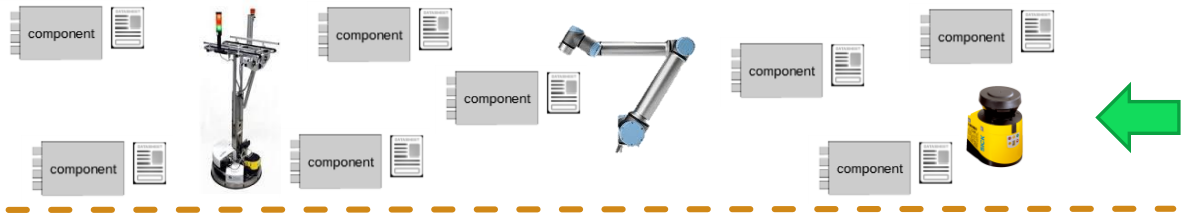
…to be technology-agnostic ***(semantics: early binding / technology: late binding)***
…to secure your design and solution efforts
…to exploit the power of combinatorics
…to benefit from low effort in modifications towards lot size 1
…to predict what you get before you build it
…to achieve robust job fulfillment by context-aware run-time decisions

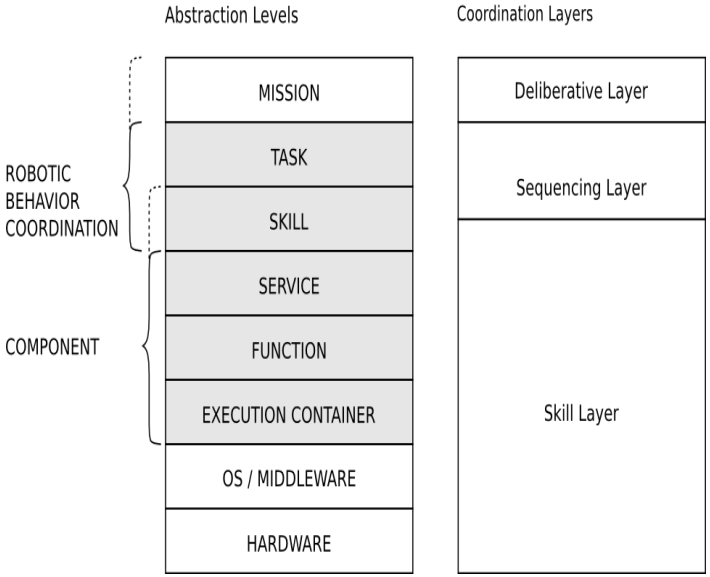




- *SmartTCL (Task Coordination with dynamic task nets)*
- *Groot (Behavior Tree)*
- *…*

https://www.igi-global.com/gateway/article/119076
https://www.sim.informatik.tu-darmstadt.de/simpar/ws/sites/DYROS2010/01-DYROS.pdf





Models…

…to be technology-agnostic

…to decouple different paces of evolution

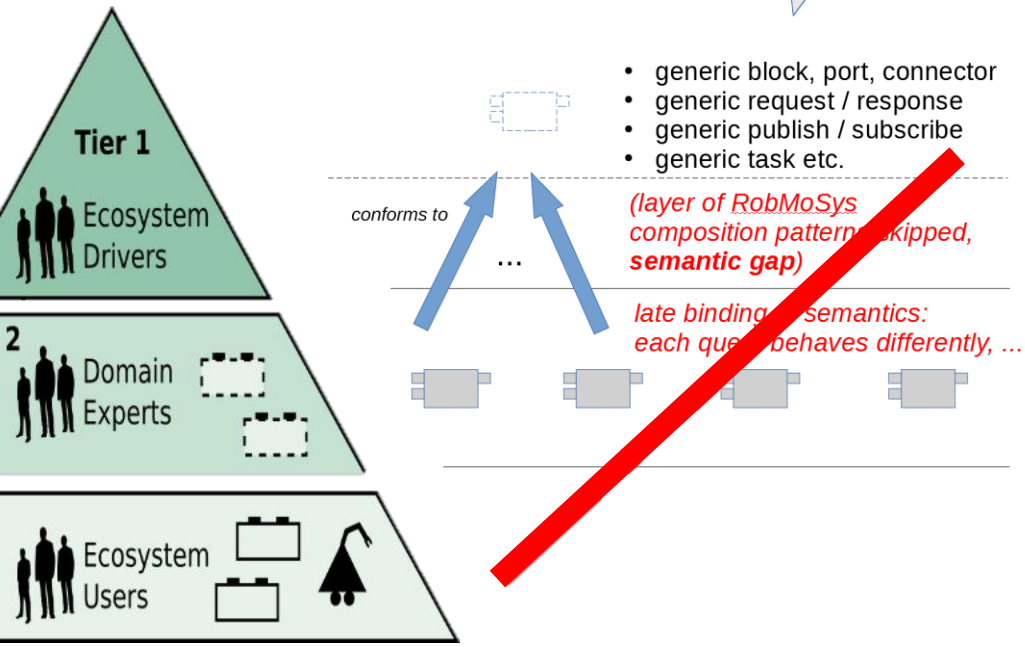
RobMoSys

Explanation: why we need early binding of semantics and late binding of technology

Early binding to a technology with an individual semantics…

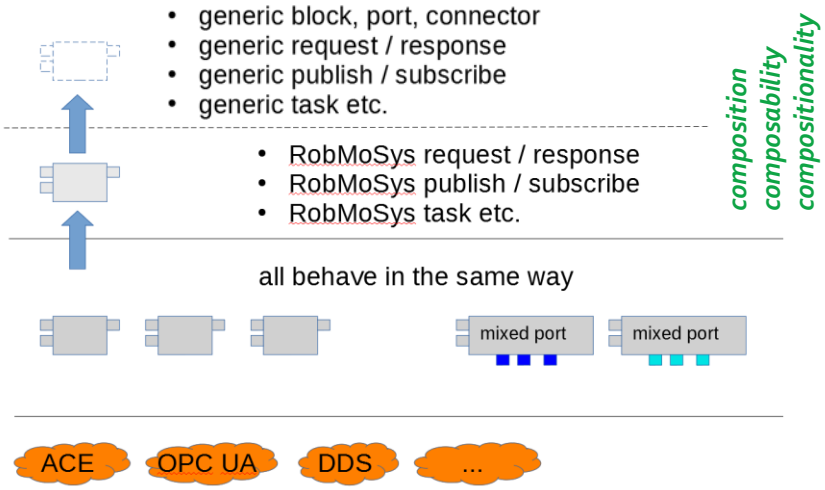
just offering too high level abstractions to the various roles with a too late binding of the semantics is not enough for composition

just like using SysML directly...



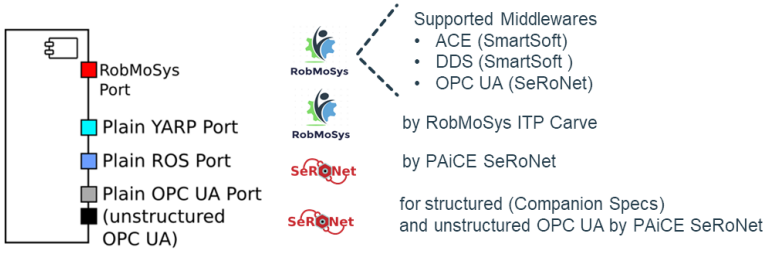
Early binding of semantics with late binding of technology

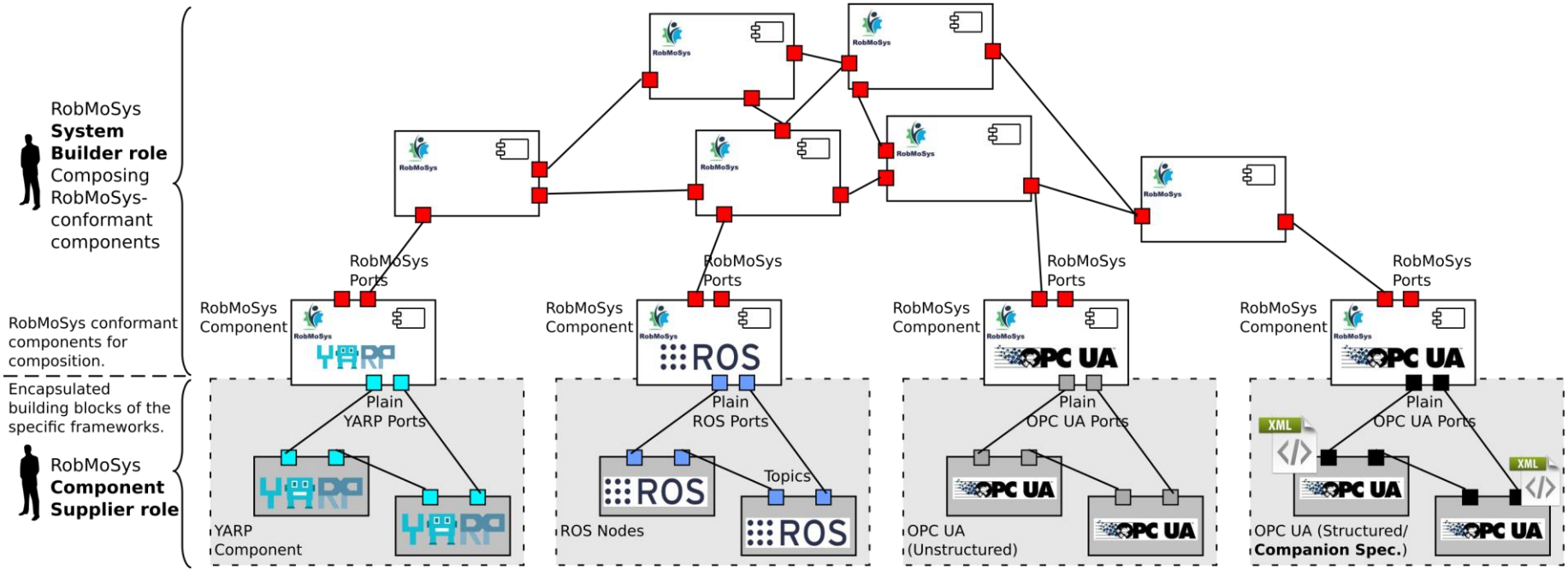
offering the RobMoSys composition structures with their semantics and late binding of technology (and not late binding of semantics)



late binding of technology:
all behave in the same way

Process: Migration Path via the Mixed Port Component



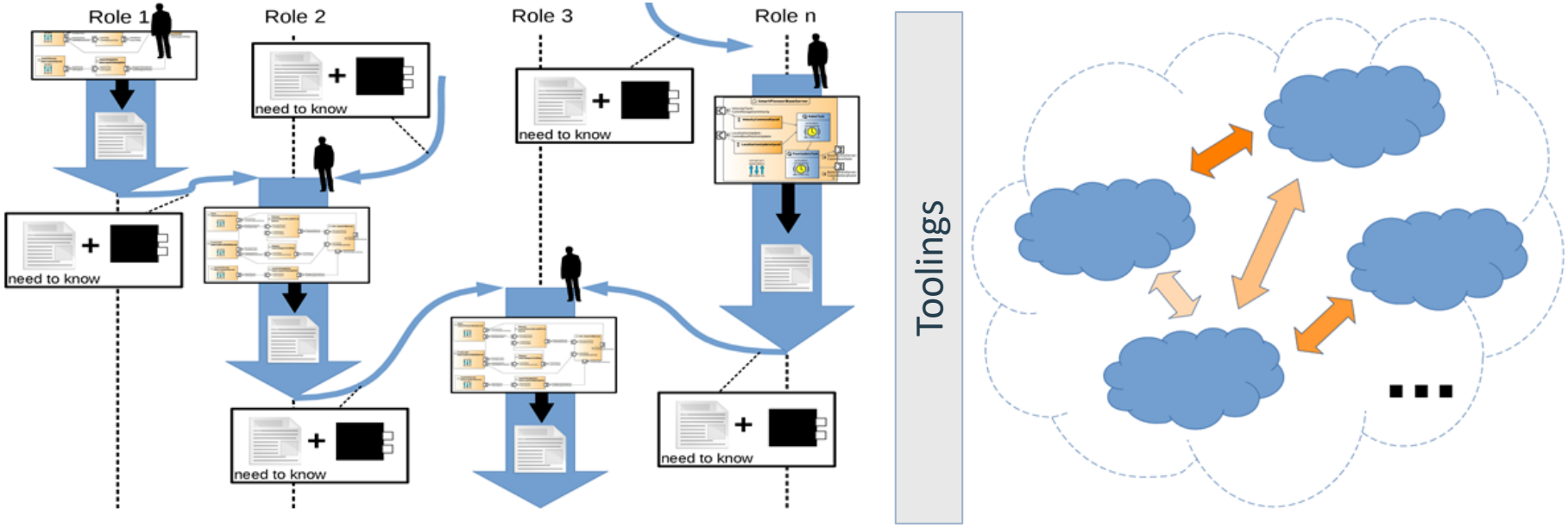


https://wiki.servicerobotik-ulm.de/tutorials:opcua-client-system:start

Process: Coverage and Conformance to enable Evolution

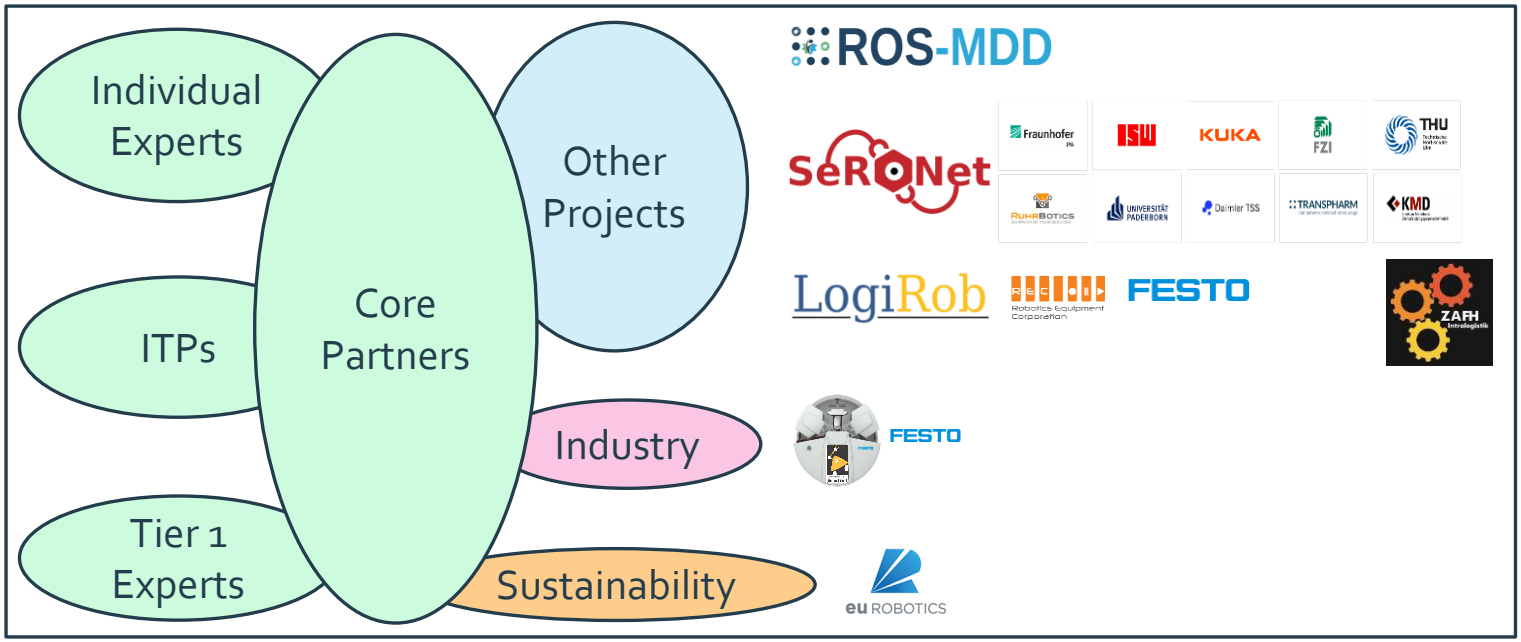
RobMoSys provides a ***concept & structure & mechanism***

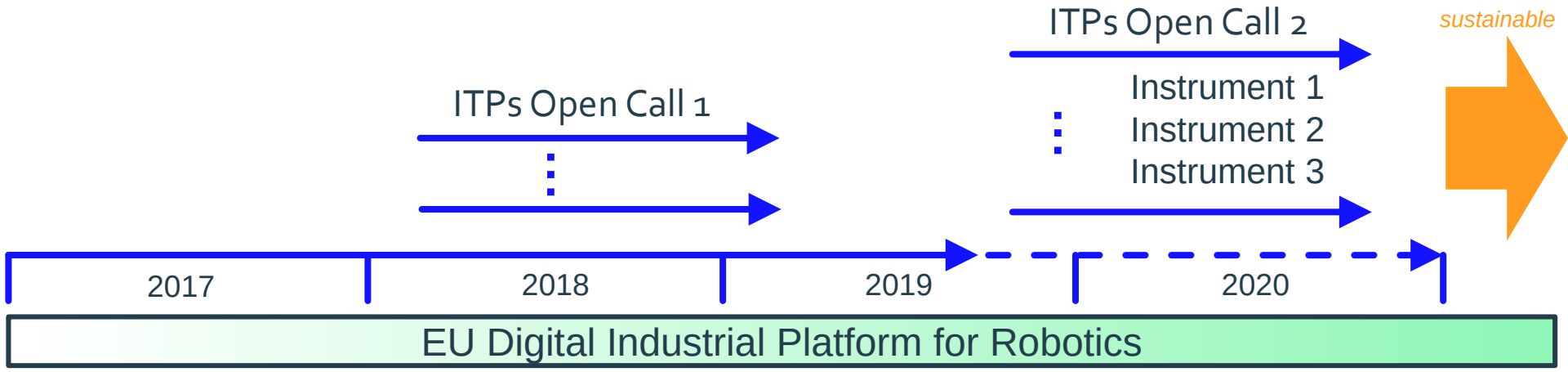
- to deal with different coexisting levels of maturity, acceptance, innovation, …
- to achieve evolvement, be inclusive, to achieve trust, to go beyond project life-times, …



Process: Community Building and Impact

RobMoSys

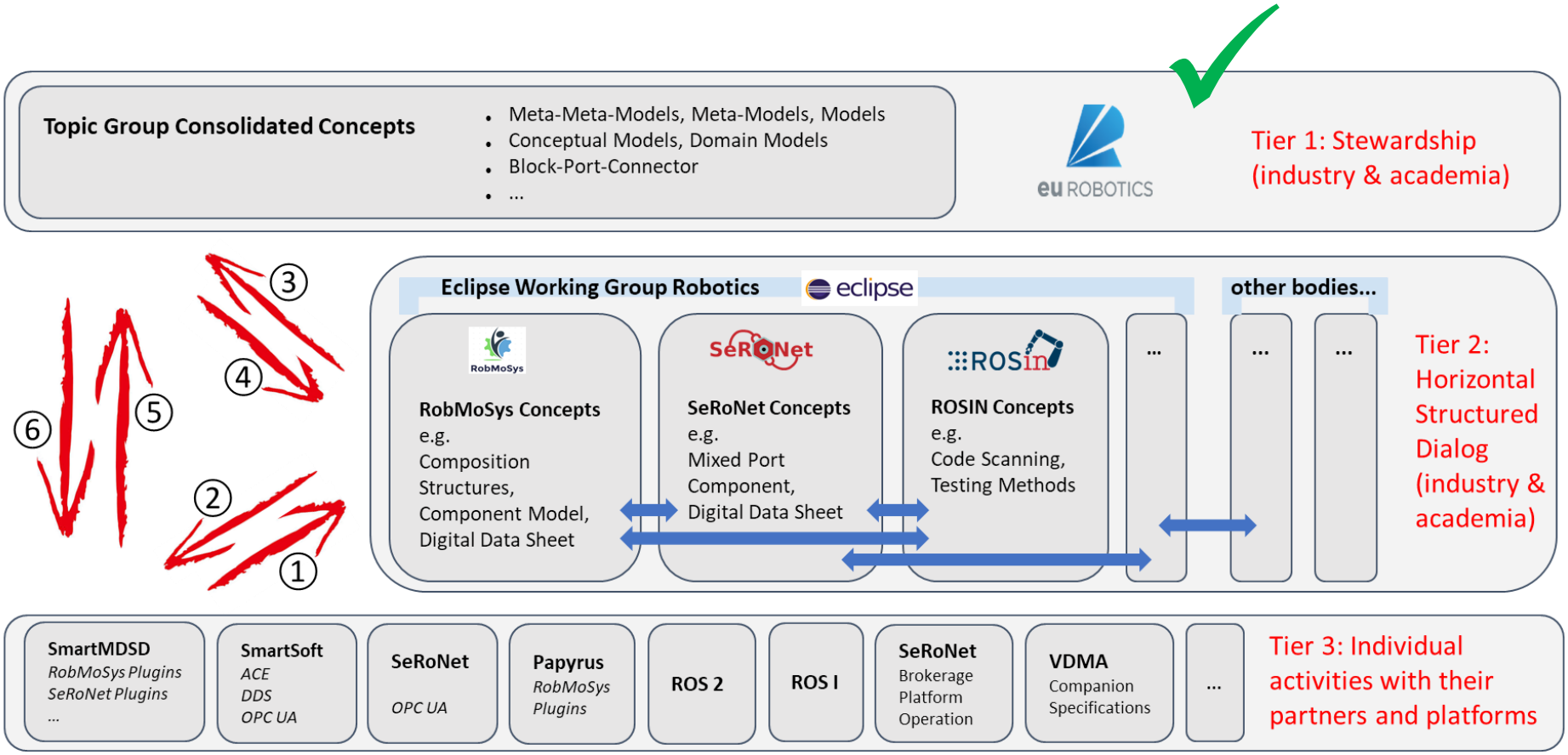




Process: Sustainability

RobMoSys provides a ***concept & structure & mechanism***

- to deal with different coexisting levels of maturity, acceptance, innovation, …
- to achieve evolvement, be inclusive, to achieve trust, to go beyond project life-times, …



Process: Sustainability

Outcome of Meeting in Munich (13.08.2019) and Telco (16.08.2019) based on the work of the *euRobotics Topic Group on Software Engineering, System Integration, System Engineering* presented at ERF 2019 in Bucharest

Establishment of the concept of Stewardship within euRobotics

euRobotics' presence as the "centre of gravity" for European roboticists, spanning research, industry and policy, makes it natural that euRobotics champion the Stewardship of "community knowledge".

Historically, euRobotics has "led the charge" to develop the Multi-Annual Roadmaps and the Strategic Research Agendas for the European robotics community, whilst at the same time setting up and enabling Topic Groups to do the community engagement and technical work to drive these processes.

Stewardship of the consolidated "body of knowledge" and steering and trusteeship of the community's "de facto" standards is a natural follow-on to this, and will form part of the Topic Group refresh process that euRobotics Directors José Saenz and Rich Walker are leading.

A working meeting with the Systems Engineering TG represented by Christian Schlegel and Dennis Stampfer, has set out a process to establish Stewardship within euRobotics in a formal way, and the Secretary General, Reinhard Lafrenz, will prepare suitable motions and briefings for the next Board of Directors meeting in late November 2019.

The vision is to have the software systems engineering body-of-knowledge as first example of a euRobotics Stewardship Body in place by the ERF 2020.

Schedule

09:00 – 09:30	*(25+5 min)*	Introduction to RobMoSys and how to get access into RobMoSys Christian Schlegel, Technische Hochschule Ulm

https://wiki.servicerobotik-ulm.de/start
https://wiki.servicerobotik-ulm.de/smartmdsd-toolchain:start

09:30 – 10:10	*(40 min)*	Interactive Tool Demo: Piecing together software components to robotics pilot applications Alex Lotz, Dennis Stampfer, Technische Hochschule Ulm
10:10 – 10:30	*(20 min)*	Part 1 of Interactive Tool Demo: Stepwise Migration to Model-Driven Development Alex Lotz, Dennis Stampfer, Technische Hochschule Ulm
10:30 – 11:00		**Coffee Break**
11:00 – 11:20	*(20 min)*	Part 2 of Interactive Tool Demo: Stepwise Migration to Model-Driven Development Alex Lotz, Dennis Stampfer, Technische Hochschule Ulm
11:20 – 12:00	*(40 min)*	Safety-analysis by model-driven tooling Huascar Espinoza, CEA List
12:00 – 12:30	*(30min)*	The Role of Higher-order Models in Robotics and its Reasoning Challenges Herman Bruyninckx, KU Leuven