RobMoSys

Modeling Principles and Modeling Foundations

Composition and Separation of Roles in a Robotics Ecosystem

Composable Models and Software for Robotics Systems:
Towards an EU Digital Industrial Platform for Robotics

First RobMoSys Brokerage Day, Leuven
5th July 2017

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What is the aim of RobMoSys?

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Composable Models and Software for Robotics Systems: Towards an EU Digital Industrial Platform for Robotics

- **RobMoSys** envisions an integrated approach built on top of the current code-centric robotic platforms, by applying model-driven methods and tools.
- **RobMoSys** will enable the management of the interfaces between different robotics-related domains in an efficient and systematic way according to each system's needs.
- **RobMoSys** aims to establish Quality-of-Service properties, enabling a composition-oriented approach while preserving modularity.
- **RobMoSys** will drive the non-competitive part of building a professional quality ecosystem by encouraging the community involvement.
- **RobMoSys** will elaborate many of the common robot functionalities based on broad involvement of the community via two Open Calls.

Better models, as the basis for better tools and better software, which then allow to build better robotic systems

The project is open for constructive suggestions from the community, as long as "platform", "composability" and "model-tool-code" are first-class citizens of those suggestions

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What is the aim of RobMoSys? Commercial User Stories…

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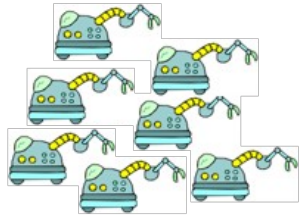
Reduction of development time

Reduced development costs

Shorter time to market

Larger production volumes possible



Certifyable systems

Predictable safety

Systems become more easily re-usable

Commoditisation of base components

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What is the aim of RobMoSys? Technical User Stories…

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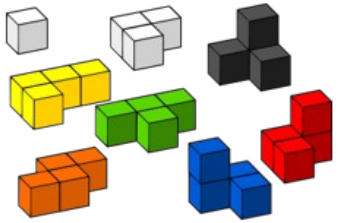
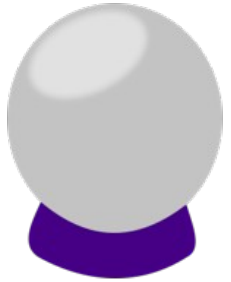
Composable components



Traceable properties

Predictable properties



Reliable quality of service

Certifyable systems

Replaceable components

Re-usable

Commoditisation of base components

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Composition, Composability, Compositionality

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- **composability** is the ability to combine and recombine *as-is building blocks* into different systems for different purposes. It requires that properties of sub-systems are invariant („remain satisfied“) under composition.
- splittability is the „inverse“ relationship of composability.
- **compositionality** requires that the behavior of a system is predictable from its sub-systems and that of the composition „glue“.
- **system composition (activity):** the activity of putting together a set of existing building blocks to match system needs with a focus on flexible (re-)combination.
- **system integration (activity):** the activity that requires effort to combine components, requiring modifications or additional actions to make them work with others.

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System Composition in an Ecosystem

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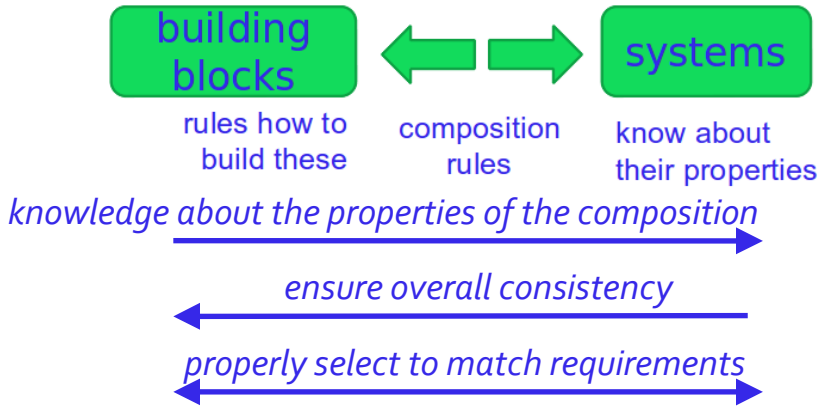
- RobMoSys adopts a **composition-oriented** approach to **system integration** that manages, maintains and assures **system-level properties**, while preserving **modularity** and independence of **existing robotics platforms** and code bases, yet can build on top of them.
- Towards an open and sustainable European robotics software **ecosystem** based on models and supporting **separation of roles**
- Apply **model-driven** techniques
- Manage **non-functional properties**
- From integration-centric to **composition-oriented** approaches

We operationalize architectural patterns and composition such that properties of system-of-systems become known in order to build trust in the system under development.

- Composition is about the **management** of the **interfaces** between different **roles** (participants in an ecosystem) in an efficient and systematic way.
- Composition is about guiding the roles via **superordinate composition-structures**.
- Composition is about explicating and managing **properties**.
- Composition is about the right **levels of abstraction and views** for roles.



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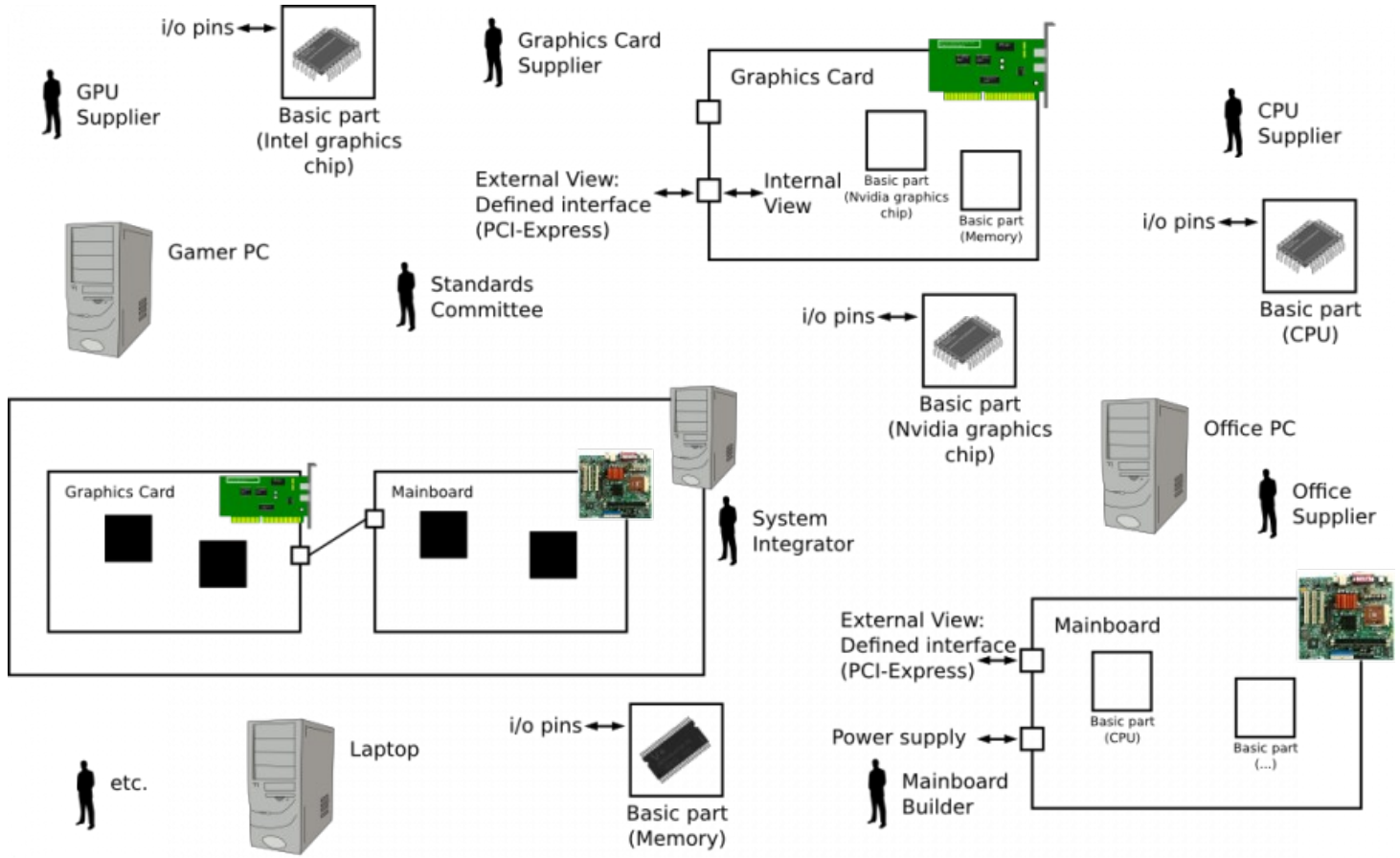
Ecosystem, Separation of Roles, Composition: PC analogy

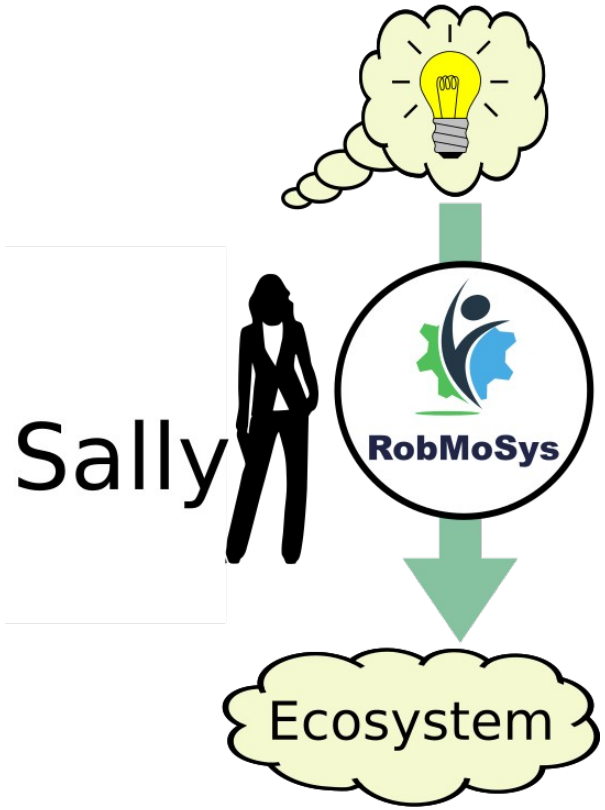


- building blocks with data sheets
- different stakeholders in different roles
- composition instead of integration

Ecosystem Participant “Sally”

RobMoSys

- Imagine you have **developed software** to localize a robot in the environment and you are interested in **making it available** in robotics.
- You are
  - a **SME,** specialized in a certain domain
  - e.g. a **component supplier** for robot navigation
- You want to
  - express your offer with pivotal features such that others can find your component (yellow pages)
  - ensure that others can use your component (composability+compositionality)
  - explicate non-functional properties of your component and define its variation points



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Ecosystem Participant “Max”

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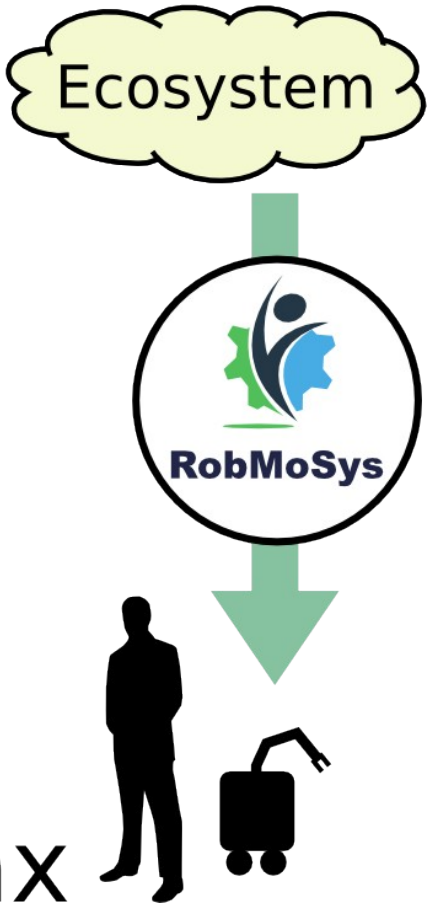
- Imagine you as an integrator are willing to develop an application which **needs a localization** module and you are interested in **integrating the third-party localization** software on your intralogistics mobile platform.
- You are
  - a **SME** that wants to **access robotics technology** and that wants to **build a robot** application
- You want
  - to **select components** from the market matching your expressed needs
  - your application to be **correct by construction**:
    you expect that building blocks seamlessly fit together
  - to view components as **grey-boxes** and use them “**as-is**”:
    adjust only at explicated variation points within modeled boundaries,
    do not modify source code



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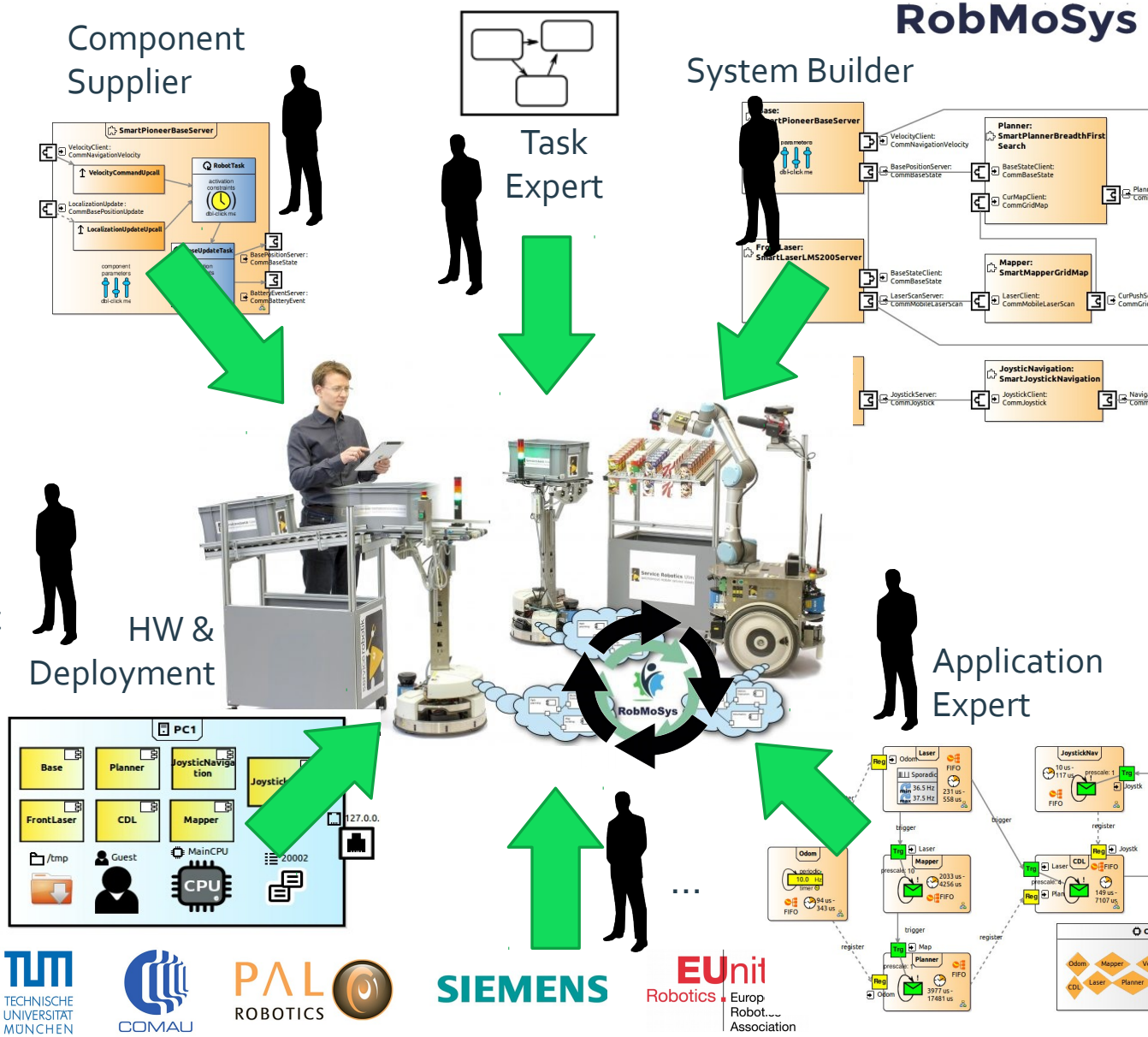
Ecosystem, Separation of Roles, Composition

- **RobMoSys enables the composition of robotics applications with managed, assured and maintained system-level properties via model-driven techniques**
- RobMoSys enables **communication of design intent, analysis of system design** before it is being built and **understanding of design change impacts**
- RobMoSys enables systems **correct by construction**
- RobMoSys supports management (design, assurance, traceability) of **(extra-functional) system properties** (e.g. resources, safety, QoS, accuracy, adequateness, etc.) in all development phases and at run-time:
  - deliver goods in time
  - trade-off energy consumption, speed, safety, etc.



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Technical User Stories and Benefits

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- Composable commodities for robot navigation with traceable and assured properties
- Description of building blocks via model-based data sheets
- Replacement of components and again matching all the attached constraints (requirements, system, building blocks)
- Composition of components and managing all the dependencies, e.g. mounting a camera on a manipulator
- Quality of Service and management of resource shares
- Determinism when you change the processing platform, e.g. keep cause-effect-chains valid
- Free from hidden interference when you add further components to a system
- Management of non-functional properties and tool-supported trade-off
- Manage gap between design time assumptions and run time situation via e.g. sanity checks
- System analysis tools for what-if questions, trade-off analysis etc.
- Task modeling for task-oriented robot programming
- Safety and shift from fail-safe to safe-operational (not just "the following things cannot happen" but "the system only behaves like that")
- …

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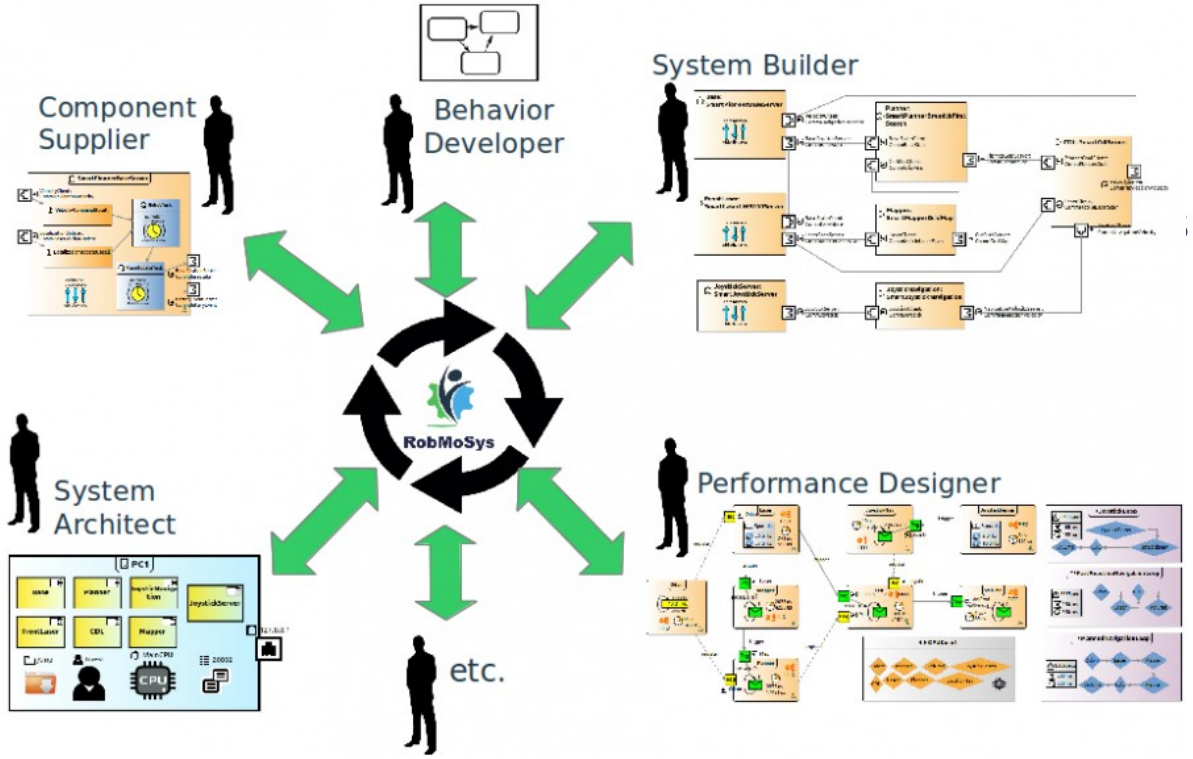
RobMoSys: Roles and Views

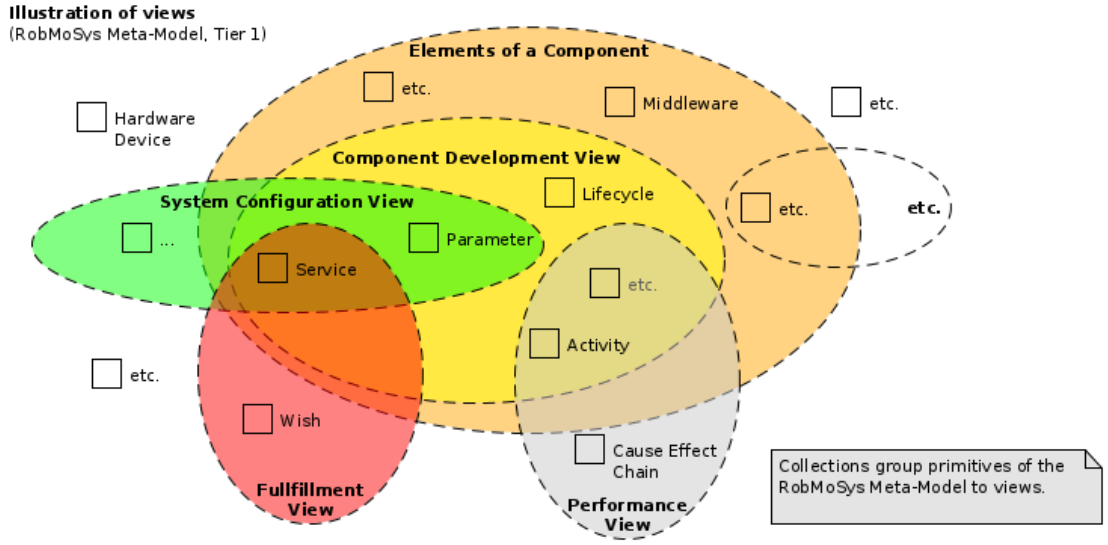
The participants in the ecosystem take one or several ***roles*** to use and supply building blocks, e.g.

- Behavior Developer
- Component Supplier
- Function Developer
- Performance Designer
- Safety Engineer
- Service Designer
- System Architect
- System Builder

Each role uses dedicated ***views*** to work on models, the modeling twin and the building block, e.g.

- Communication Pattern View
- Component Development View
- Execution Container View
- Service Design View
- System Configuration View
- Performance View
- Deployment View
- Service Architecture View
- Service Fullfilment View





RobMoSys Ecosystem Organization

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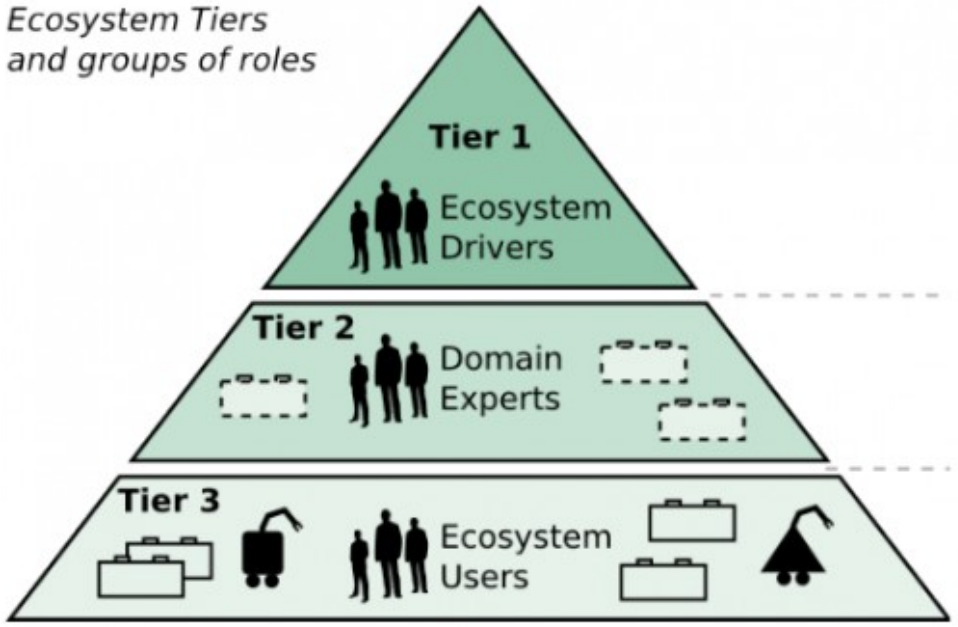
Ecosystem Tiers and groups of roles



Examples of the PC Analogy:

e.g. Semiconductor standards, computer architecturve, USB, PCIe, modern use of ethernet, etc.

e.g. laptop PC, desktop PC, industry PC, ATX, ITX, Mini-ITX, VGA, HDMI, SATA, IDE, CPU socket, GPU socket, etc.

e.g. graphics card, CPU, TPM, Memory, power supply, etc.

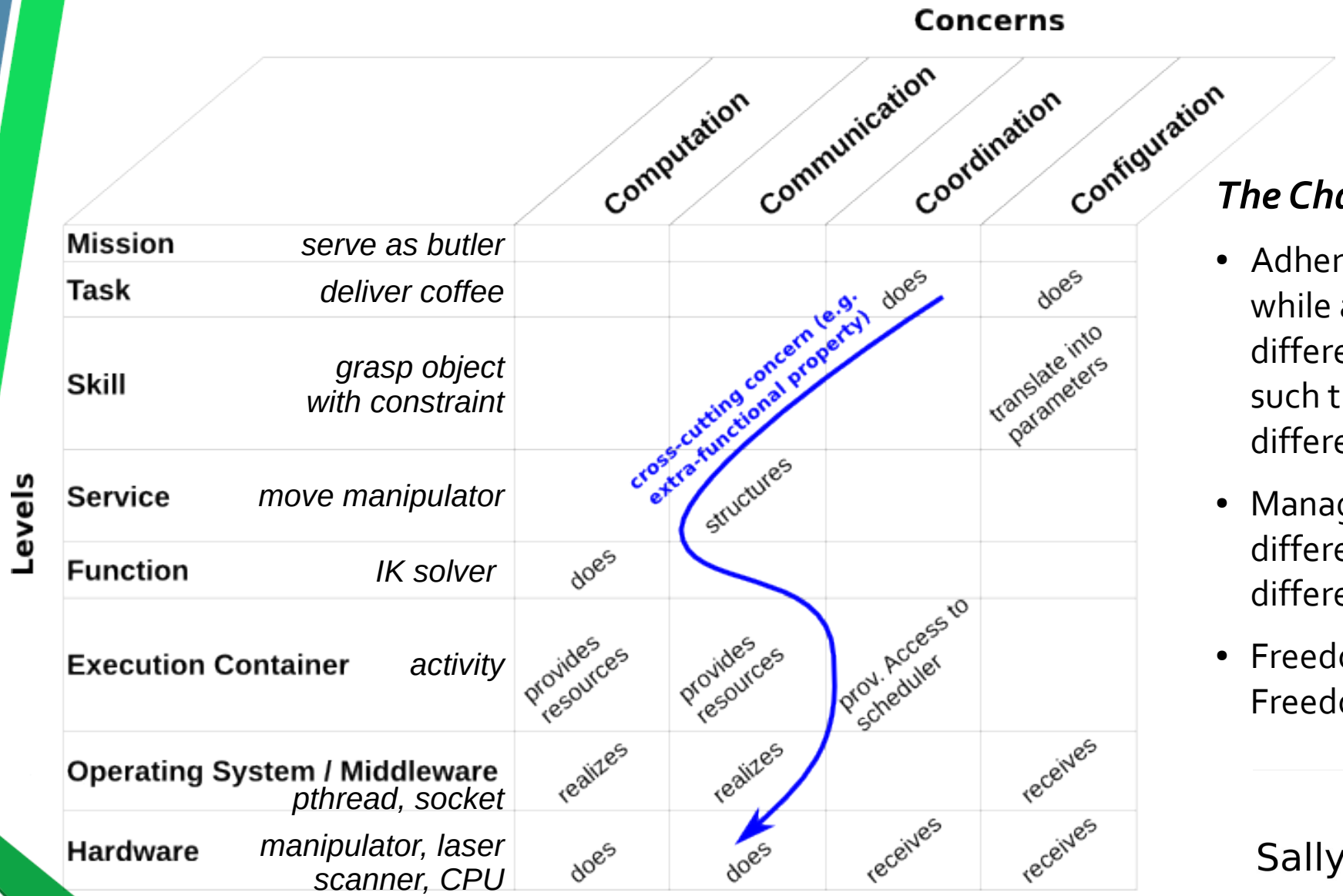
Examples of Robotics:

e.g. robotics architectural patterns and robotics composition structures (service-oriented software component model, robotics task models etc.)

e.g. Flexible Navigation Stack, Active Object Recognition, Motion Stack, Perception Stack etc.

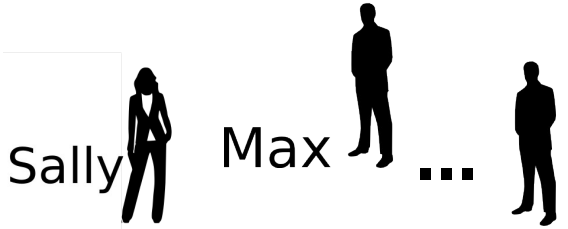
e.g. robotics software components (Motion Planning, SLAM, Object Recognition), robotics functional libraries (MRPT, OpenCV, PCL), applications (Pilots, Logistics Fleet, Production Cell, Healthcare Servicerobot), etc.

Abstraction Levels and Concerns



The Challenge:

- Adhere to separation of concerns while at the same time, package different concerns into structures such that these fit the views of the different roles.
- Manage interfaces between different roles and between different levels of abstractions
- Freedom of Choice versus Freedom from Choice



How to build models for different parts and different aspects of a robotic system?

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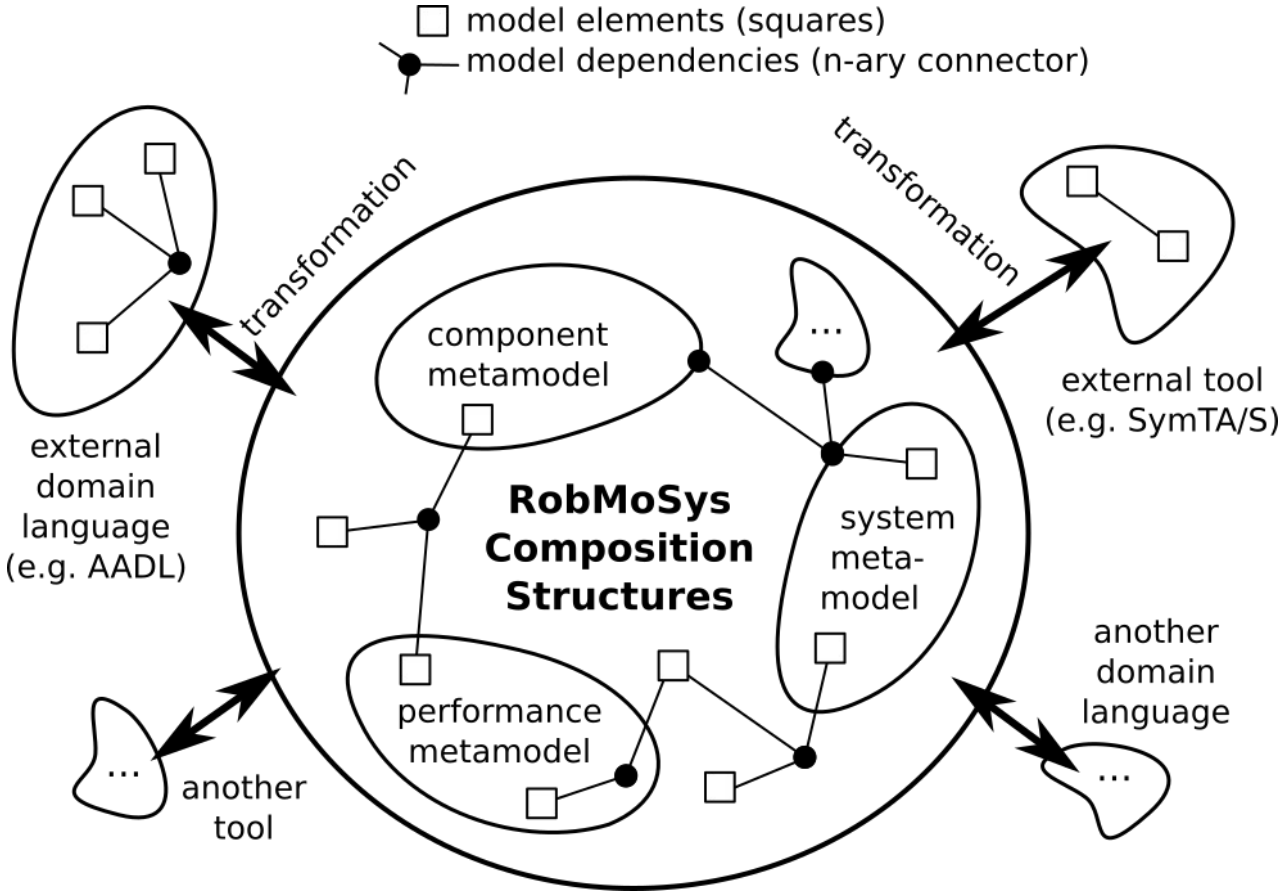
- be able to correctly compose models
- be at least as detailed as needed for a certain level of confidence into the properties of the outcome (by simulation, by testing, by reasoning, …)
- cannot be done easily as long as you do not adopt to a notion of Meta-Models
- Meta-Models allow to transform in a consistent way between models including constraints, tolerances etc.



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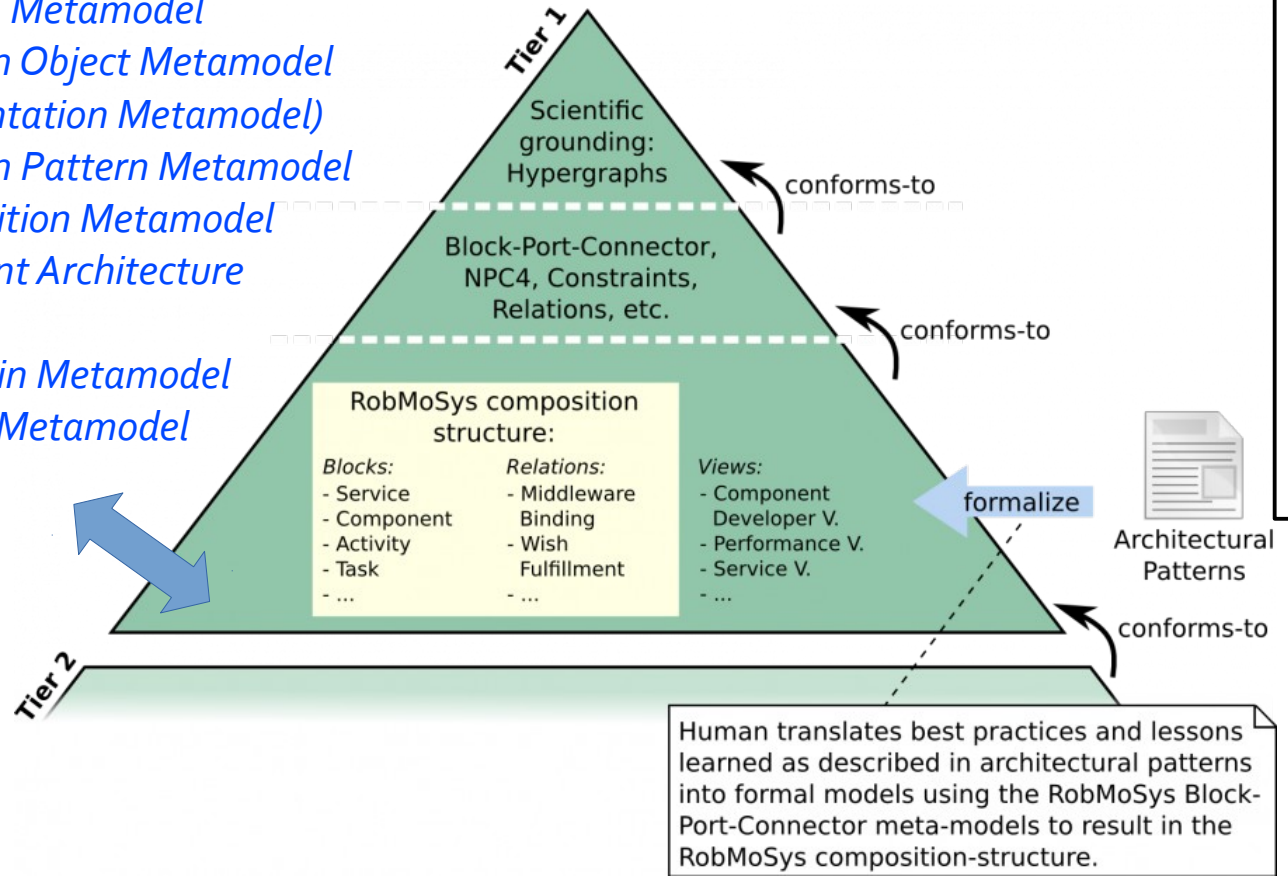
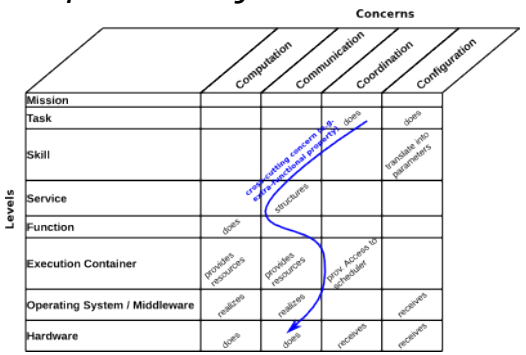
Tier 1 Modeling Foundations

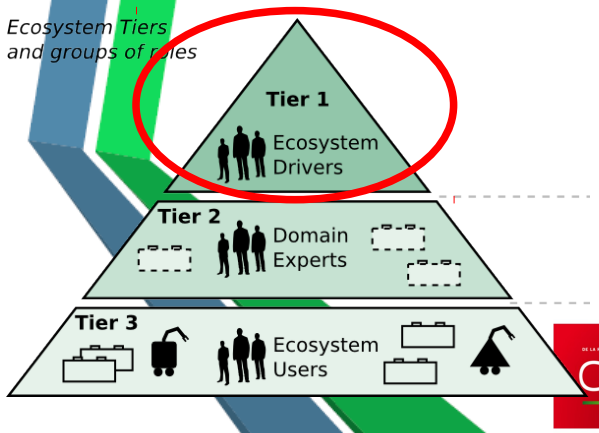
Tier 1 provides the **general structures for composition.** Three levels can be distinguished:

- *Service-Definition Metamodel*
  - *Communication Object Metamodel (Data Representation Metamodel)*
  - *Communication Pattern Metamodel*
- *Component Definition Metamodel*
- *System Component Architecture Metamodel*
- *Cause-Effect-Chain Metamodel*
- *Robotic Behavior Metamodel*
- *…*

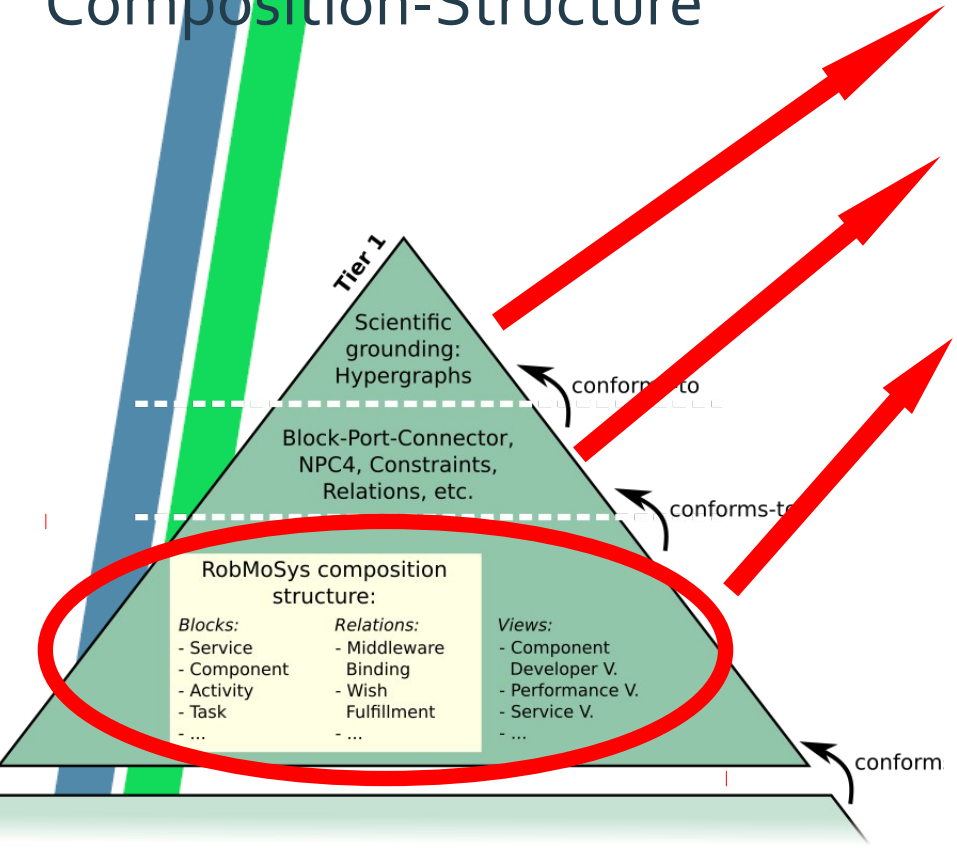


Architectural Patterns:
- levels / concerns
- composability
- separation of roles

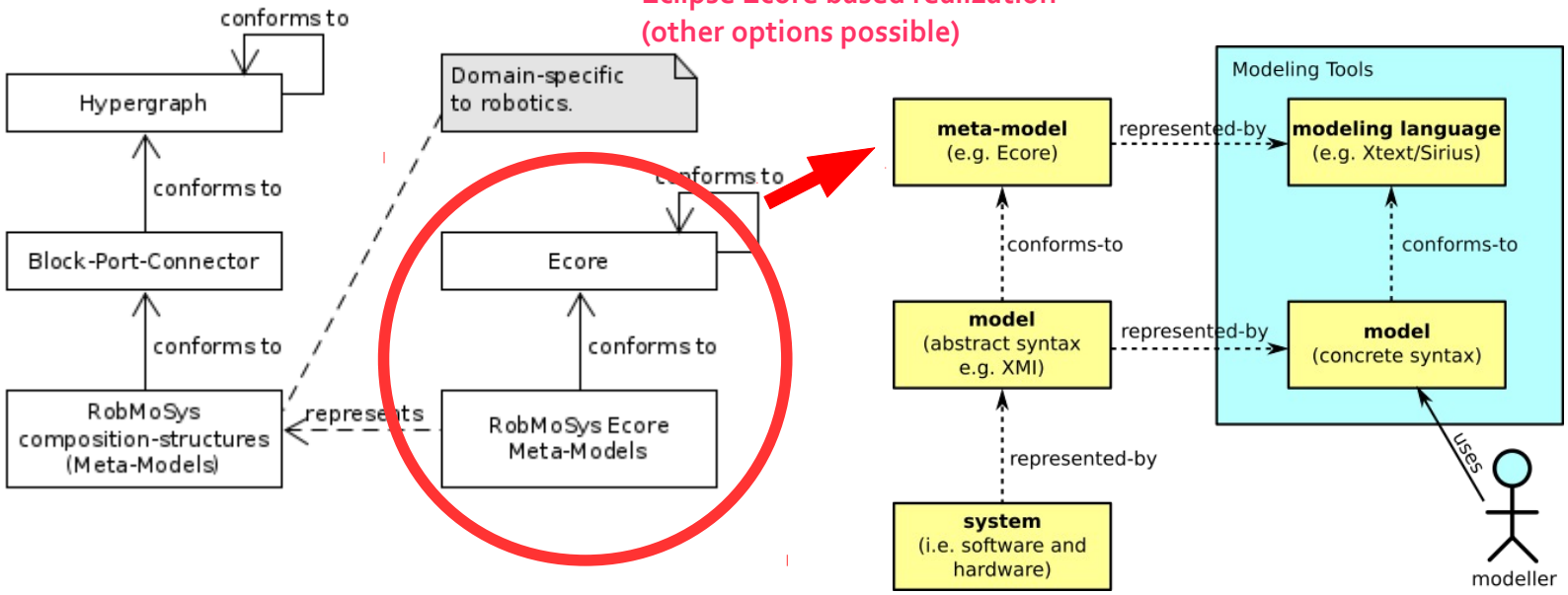




Realization of RobMoSys Composition-Structure

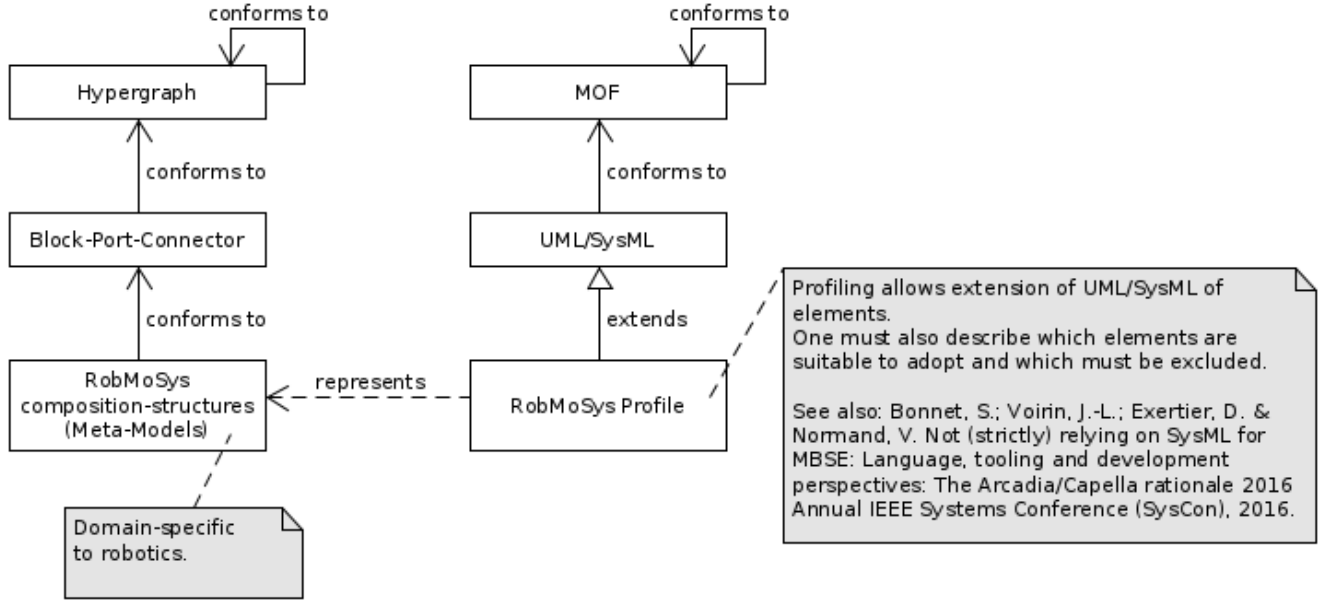


Eclipse Ecore based realization (other options possible)



Alternative 1

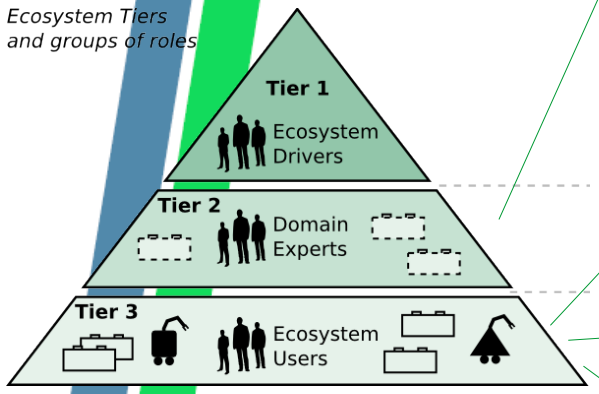
Alternative 2

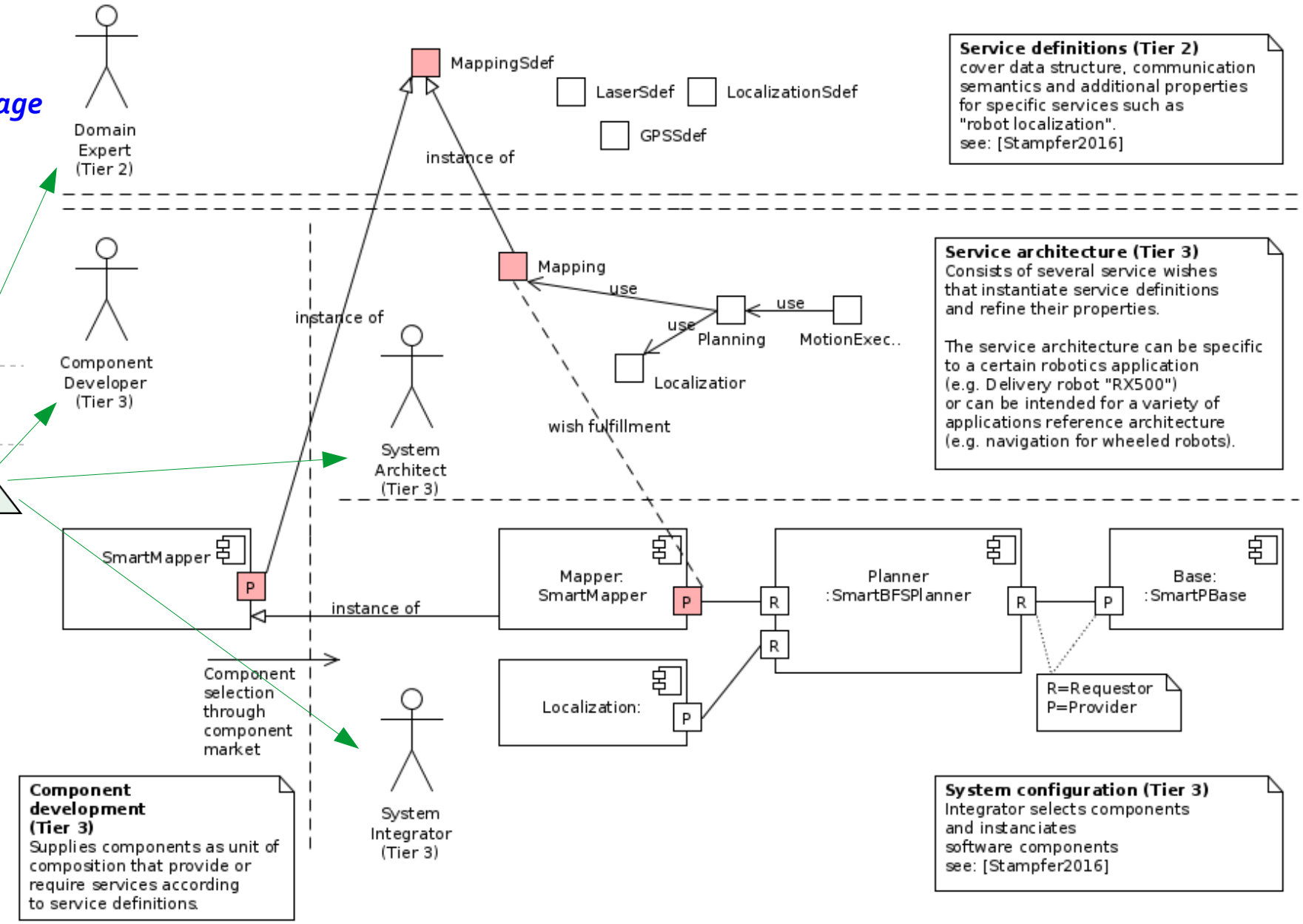


Service-Based Composition Workflow

Tier 2: Service Definition

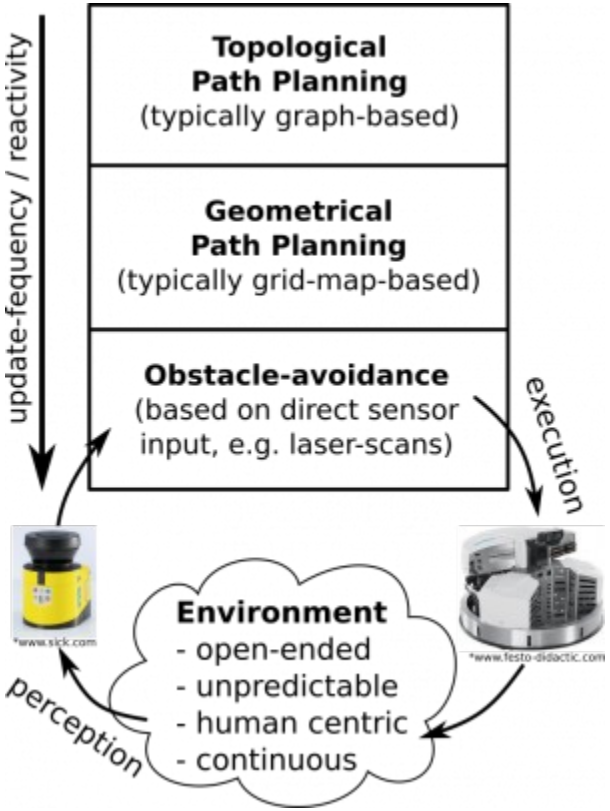
Tier 3: Service Realization / Usage





Tier 2
Example of Domain Models

- **Flexible Navigation Stack**
- Active Object Recognition
- Motion Stack
- Perception Stack
- ...



Tier 3
Existing Building Blocks and Scenarios

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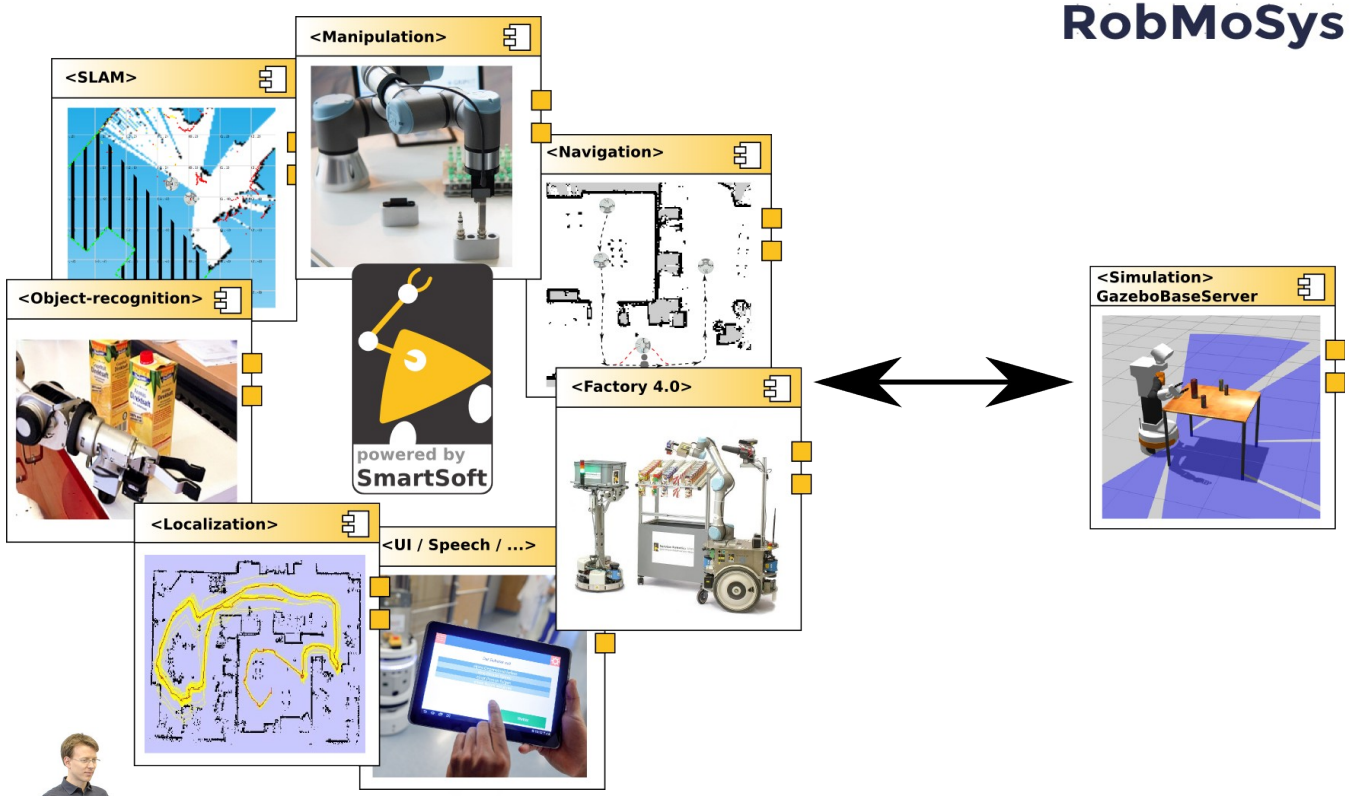

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Pilots

- under preparation
- see RobMoSys Wiki

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Pilot 1: Goods Transport in a Company
Intralogistics Industry 4.0 Robot Fleet (HSU)

Pilot 2: Mobile Manipulation for manufacturing applications on a product line
Flexible Assembly Cell (Siemens)

Pilot 3: Mobile manipulation for assistive robtotics in a domestic environment or in care institutions
Assistive Mobile Manipulation (PAL)

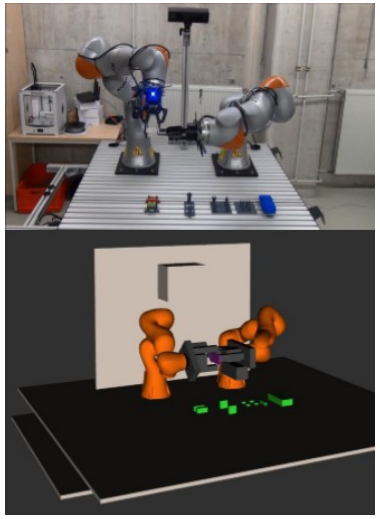
Pilot 4: Modular Educational Robot (COMAU)

Pilot 5: Human Robot Collaboration for Assembly (CEA)
and further pilots

the project is open for constructive suggestions from the community for further pilots, as long as "platform", "composability" and "model-tool-code" are first-class citizens of those suggestions

Pilot 1

Pilot 2



Pilot 3

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