Modeling and Tooling for Robotics Software Development

The RobMoSys Consortium

ROS-Industrial Conference 2019
Dec. 10-12 2019, Stuttgart, Germany

About

- **The Speaker:** Dennis Stampfer
  - 10+ years into robotics software engineering for service robotics
  - Focus: Tooling via Model-Driven Software Engineering
  - THU takes role of the Technical Lead in RobMoSys

- **The Project:** RobMoSys H2020 Innovation Action:
  - Composable Models and Software for Robotic Systems
  - 4 Years, 01/2017-12/2020, Budget 8M, where 4 M for Open-Calls
  - EU Digital Industrial Platform for Robotics, together with ROSIN
  - http://robmosys.eu/

- **The Relations:** (here @ ROS Industrial Conference)
  - SeRoNet (Next Talk, Björn Kahl)
  - MROS: Metacontrol for ROS2 (RobMoSys ITP/"Sub-Project": Carlos Hernandez Corbato)
  - ROS Model (Day 2, Nadia Hammoudeh Garcia)
  - Eclipse Foundation (Day 3, Philippe Krief)
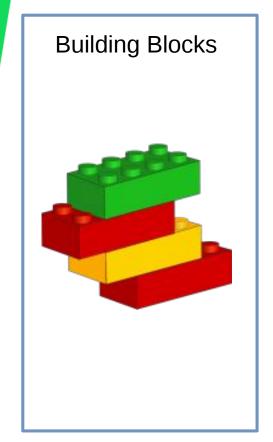
Outline

- Challenges in robotics
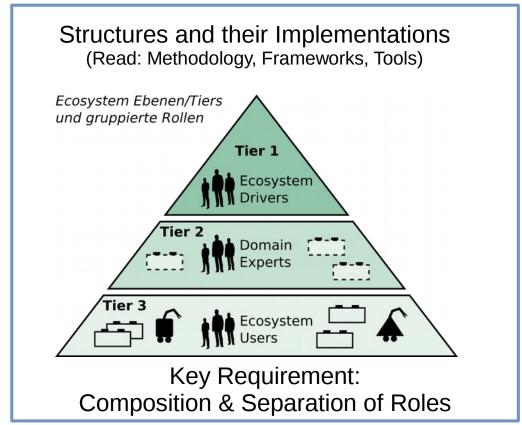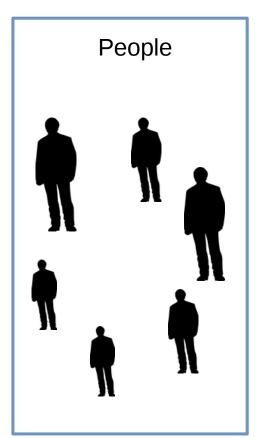
- Tooling & Industry use-case(s)

Challenges in robotics software development

(to provide some context)

Challenges in Robotics Software Development: Integration (at least one of them)

RobMoSys

Building Blocks	Structures and their Implementations (Read: Methodology, Frameworks, Tools)	People

Ecosystem Ebenen/Tiers und gruppierte Rollen

Tier 1 — Ecosystem Drivers

Tier 2 — Domain Experts

Tier 3 — Ecosystem Users

Key Requirement:
Composition & Separation of Roles

ROS 2 3 :)

PLATTFORM INDUSTRIE 4.0

OPC UA

powered by SmartSoft
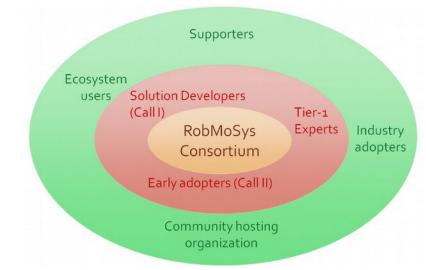
YARP

RobMoSys Roadmap – The Big Picture

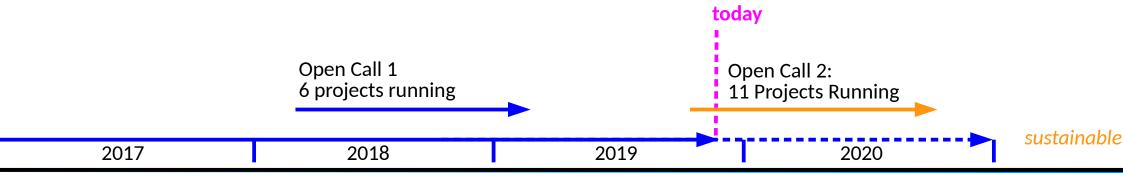**Model-driven engineering** as key enabler for
- complex software and system integration
- integrating existing technologies

Results
- consolidated best practices
- tooling for correct-by-construction composition and code generation
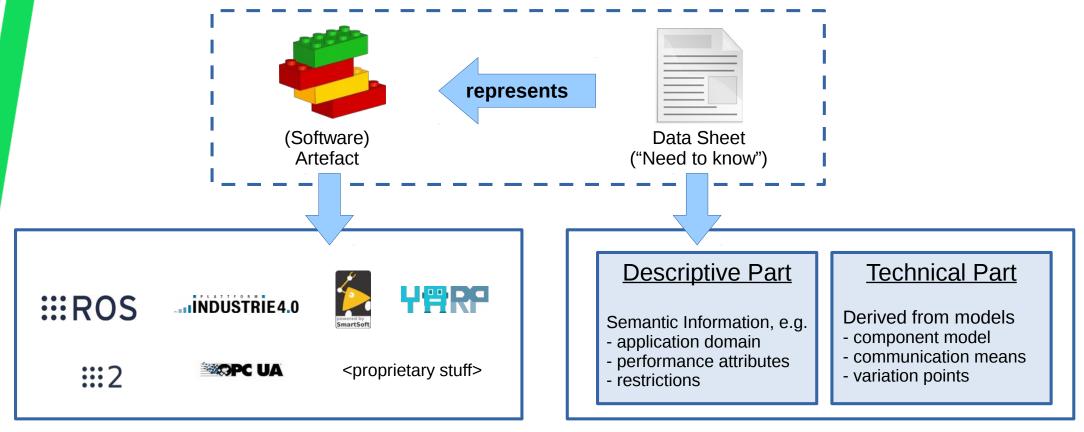- open-source software and tools

4M € to third party via open calls:

today

Open Call 1
6 projects running

Open Call 2:
11 Projects Running

sustainable

| 2017 | 2018 | 2019 | 2020 |

EU Digital Industrial Platform for Robotics

Model-Driven Development with the Digital Data Sheet

RobMoSys

represents

(Software)
Artefact

Data Sheet
("Need to know")

:::ROS •••INDUSTRIE4.0 SmartSoft YARP

:::2 OPC UA <proprietary stuff>

Descriptive Part

Semantic Information, e.g.
- application domain
- performance attributes
- restrictions

Technical Part

Derived from models
- component model
- communication means
- variation points

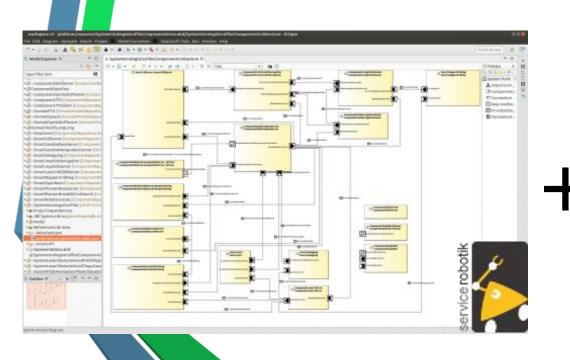... but people are developers! -- Did someone mention tooling?

Tooling for Robotics Software Development: Industry Use-Case

Tooling + Industry Use-Case

- TIAGo Base @ Intralogistics
- High flexibility required, depending on customer's needs:
  - Different sensors
  - Different software
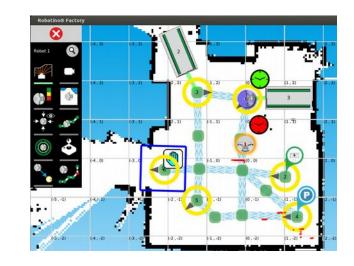- Tooling (IDE) is key for quick developer response: SmartMDSD Toolchain

Part I: The Navigation Stack
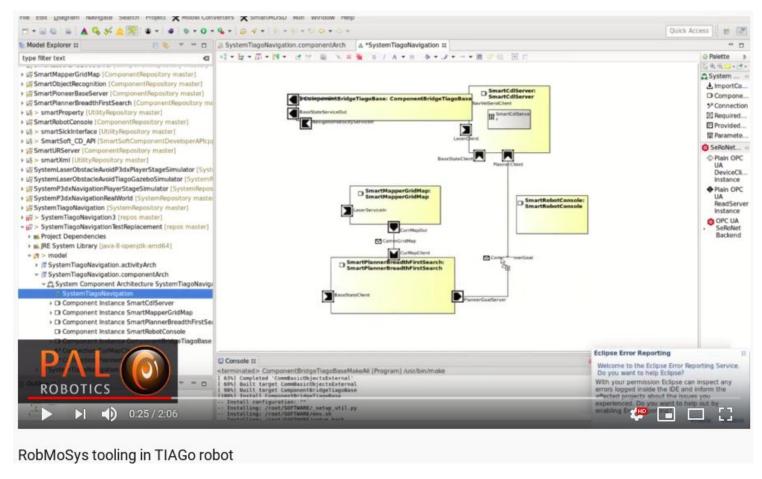

TIAGo Base:
100% ROS-based

+

Corridor-based fleet Navigation:
100% SmartSoft-based

=

... or not?
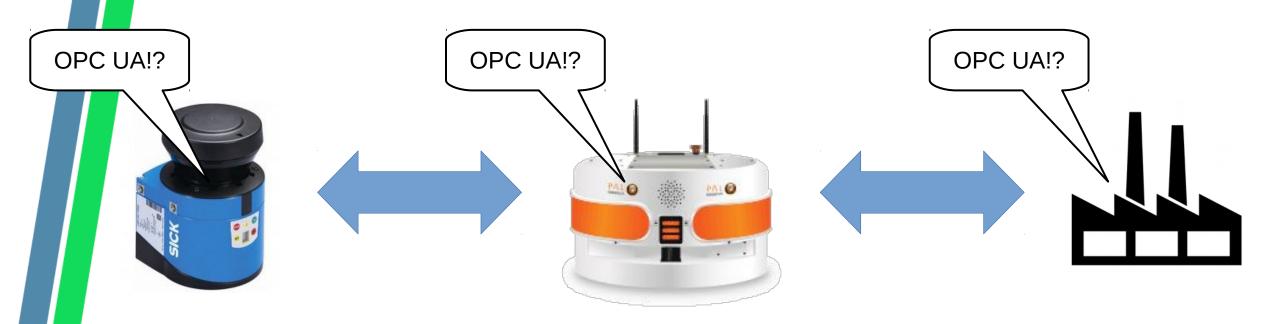
Part I: The Navigation Stack

RobMoSys tooling in TIAGo robot

https://www.youtube.com/watch?v=FCvK9dAZXPo

„There Is No Industry 4.0 without OPC UA"

Stefan Hoppe, Global Vice President, OPC Foundation

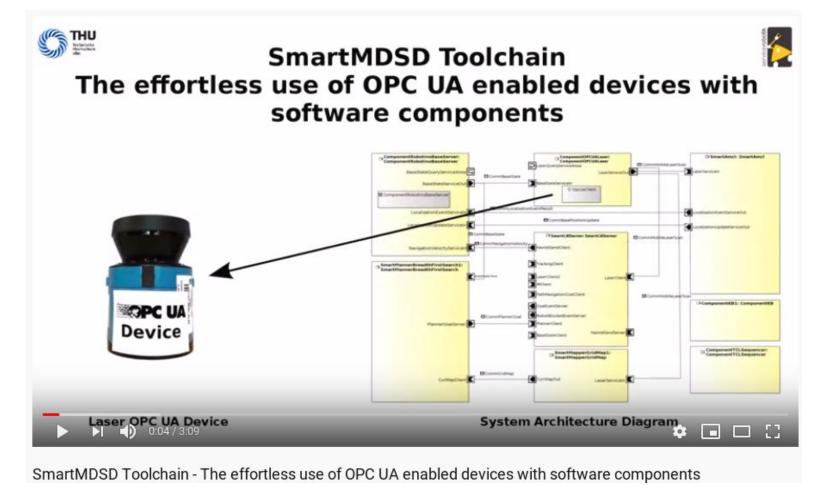... that holds true for: Robots, Devices, Software Building Blocks

SmartMDSD Toolchain - The effortless use of OPC UA enabled devices with software components

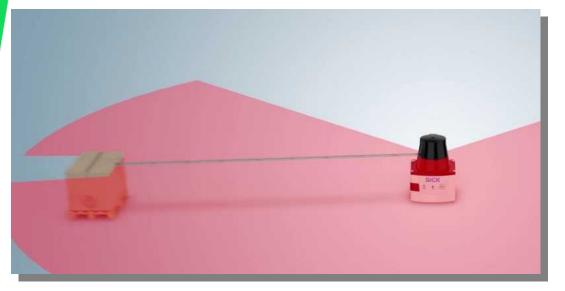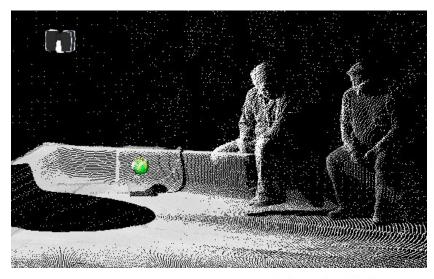https://www.youtube.com/watch?v=Xi7Irjk8Kyw

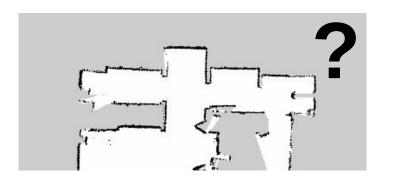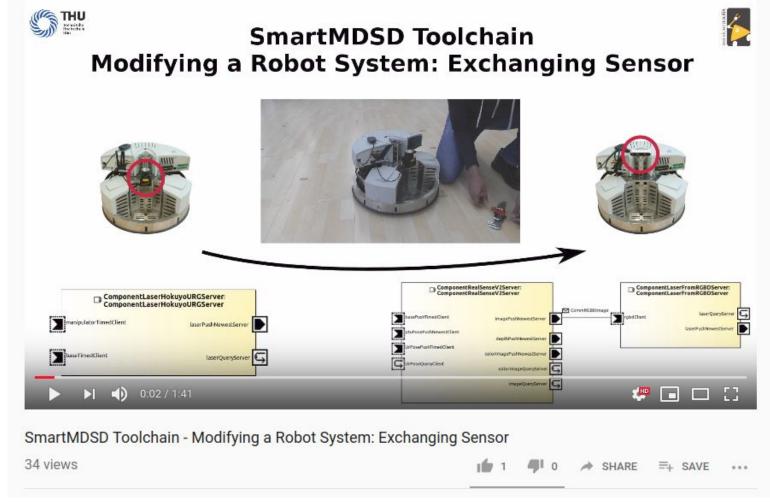# Part III: Replacement of Components

Part III: Replacement of Components

https://www.youtube.com/watch?v=RHvvb6lTHG4
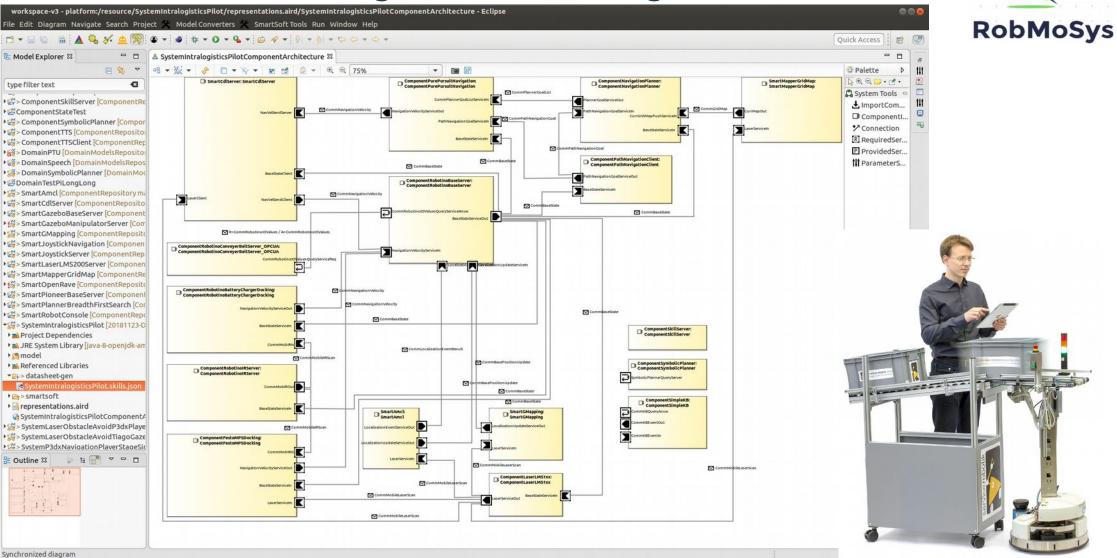
Part IV: Middleware Agnostic Modeling

Part V: Tooling Interoperability

Digital Data Sheet as means to enable tooling interoperability.
Here: Behavior Tree Editor + Robotics IDE
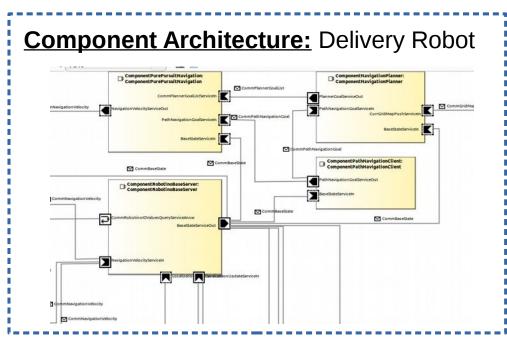
Tasks: Deliver Euro-Container from A to B

Groot — The fancy BehaviorTree Editor

SmartTCL

Component Architecture: Delivery Robot

SmartMDSD Toolchain with:

powered by SmartSoft

OPC UA

:::ROS

Part V: Tooling Interoperability
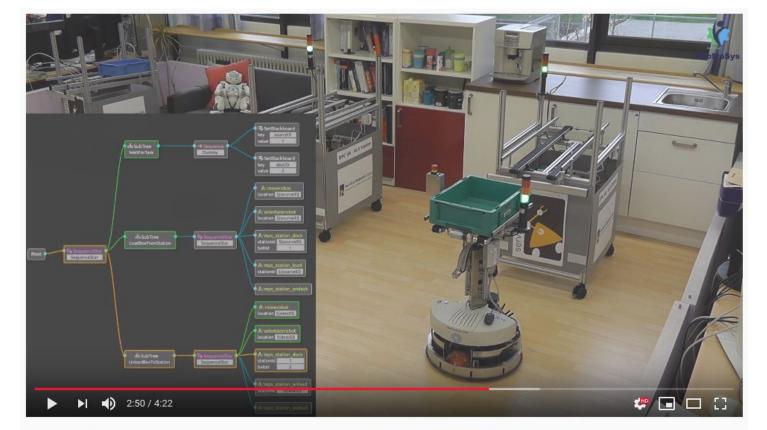

Robotic Behavior in RobMoSys using Behavior Trees and the SmartMDSD Toolchain

https://www.youtube.com/watch?v=54_skOuHsds
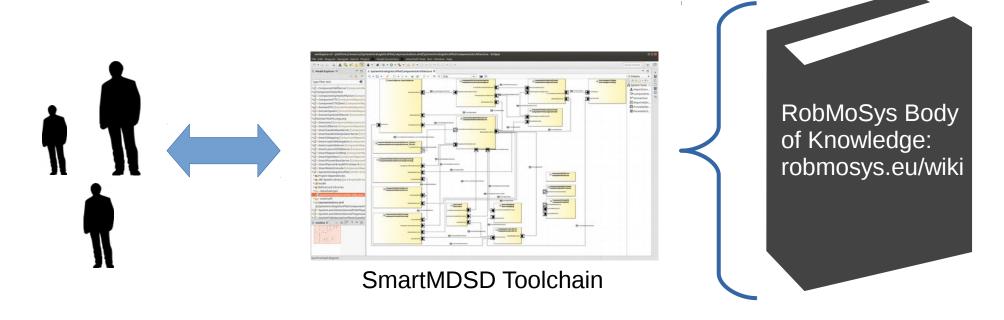
Why does that work?

- Thanks to Modeling, Best-Practices for Composition, Digital Data Sheet, …

- **Accessible via tooling**

- No need for developers to learn+understand all details!

SmartMDSD Toolchain

RobMoSys Body of Knowledge: robmosys.eu/wiki
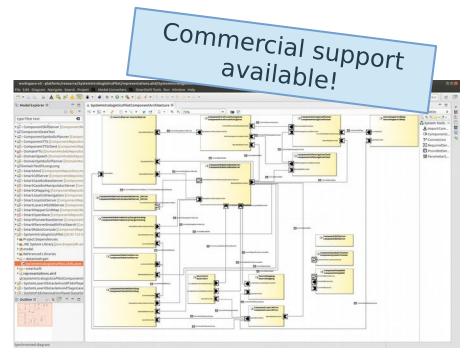
How to do it? With the SmartMDSD Toolchain!

- The SmartMDSD Toolchain is an Integrated Development Environment (**IDE**) for robotics software to support system composition.

- For **real systems development**, not for "just drawing"

- **It supports ROS!**

- Conform to RobMoSys & SeRoNet

- 10+ years, very **mature,** used in commercial products

- **100% Open-Source** @ Eclipse Foundation

Commercial support available!

# Conclusion & Take-Away

- ROS is great -- Let's not limit it by technology barriers:
  Applications should not need to care about packaging of building blocks

- We need more **IDEs to increase developers productivity**:
  The SmartMDSD Toolchain is a framework-agnostic and mature IDE; it loves ROS

- RobMoSys is:

  - a **movement** towards a new way of software engineering (via models)

  - a **community moderation** activity on **model-driven engineering**

  - more than just this talk.

  - Check out the ITPs ("sub-projects"): robmosys.eu/wiki

Opinions? Want to get in touch?
Dennis Stampfer <stampfer@hs-ulm.de> at the conference
and discourse.robmosys.eu any time

Further information

- ## RobMoSys:

  – http://www.robmosys.eu/wiki

  – http://discourse.robmosys.eu

- ## SeRoNet:

  – http://www.seronet-projekt.de

- ## SmartMDSD Toolchain:

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

RobMoSys is a community effort!
Get Involved!

Opinions? Want to get in touch?
Dennis Stampfer <stampfer@hs-ulm.de> at the conference
and discourse.robmosys.eu any time

Appendix: Additional Information

Where to get the SmartMDSD Toolchain
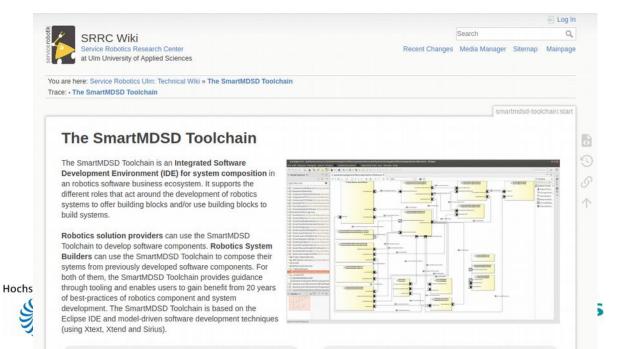
- **SmartMDSD Toolchain easy entry:**
  - Available as **pre-installed/ready-to-go virtual machine image!**
  - https://wiki.servicerobotik-ulm.de/smartmdsd-toolchain:start

- **Tutorials**

  - https://wiki.servicerobotik-ulm.de/tutorials:start

  - https://wiki.servicerobotik-ulm.de/how-tos:start

AMBITION

RobMoSys will coordinate the whole community's best and consorted efforts to realize **a step-change towards an industry-grade software development European ecosystem**

- open
- sustainable
- industrial quality

RobMoSys part of the effort on **Digital Industrial Platforms for Robotics (together with ROSIN)**

What is the aim of RobMoSys?

Composable Models and Software for Robotics Systems:
Towards an EU Digital Industrial Platform for Robotics
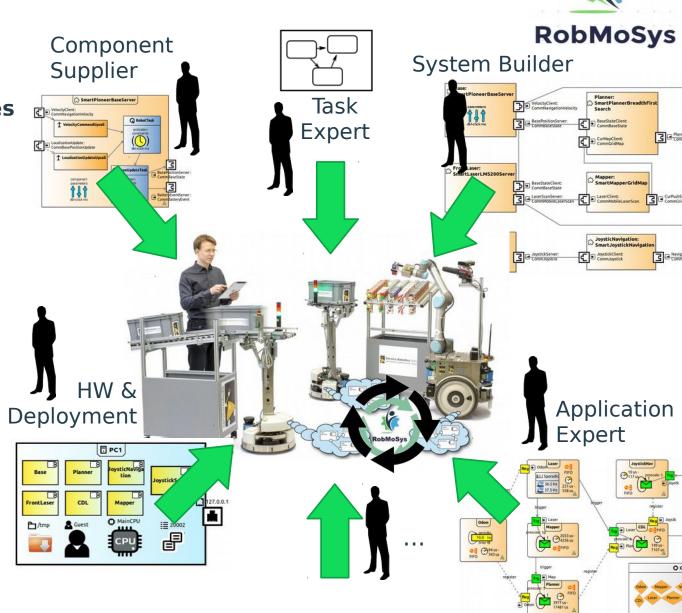
- **RobMoSys** envisions an integrated approach built on top of the current code-centric robotic platforms, by applying model-driven methods and tools.

- **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

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.

Component Supplier

Task Expert

System Builder

HW & Deployment

Application Expert

…

EU H2020 RobMoSys, German BMWi PAiCE SeRoNet

RobMoSys (Composable Models and Software for Robotics Systems) Body-of-knowledge via model-driven structures

Meta-Model:
domain-independent

Model:
domain-specific
(mobile robots, intralogistics, manipulation, …)

Implementation: components and systems

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

SeRoNet Consortium as driver Involving external experts, professional associations, ...

Companion Specificiations — OPC UA

SeRoNet User
component providers, system builders, end users, ...

Tier 1 — Ecosystem Drivers
Tier 2 — Domain Experts
Tier 3 — Ecosystem Users

SeRoNet is conform to superodinated structures consolidated at the European level via RobMoSys

EU Digital Industrial Platform for Robotics

- Technical Implementation with industry standard OPC UA - brokerage platform

See also next talk:
SeRoNet

Become Part of RobMoSys...

- **RobMoSys Web Page => https://www.robmosys.eu**
  - access point which guides you to more information according to your role and interest
  - role-specific entry points will be improved with respect to Open Call 2

- **Subscribe to Newsletter**
  - easiest way to follow at a high level of abstraction
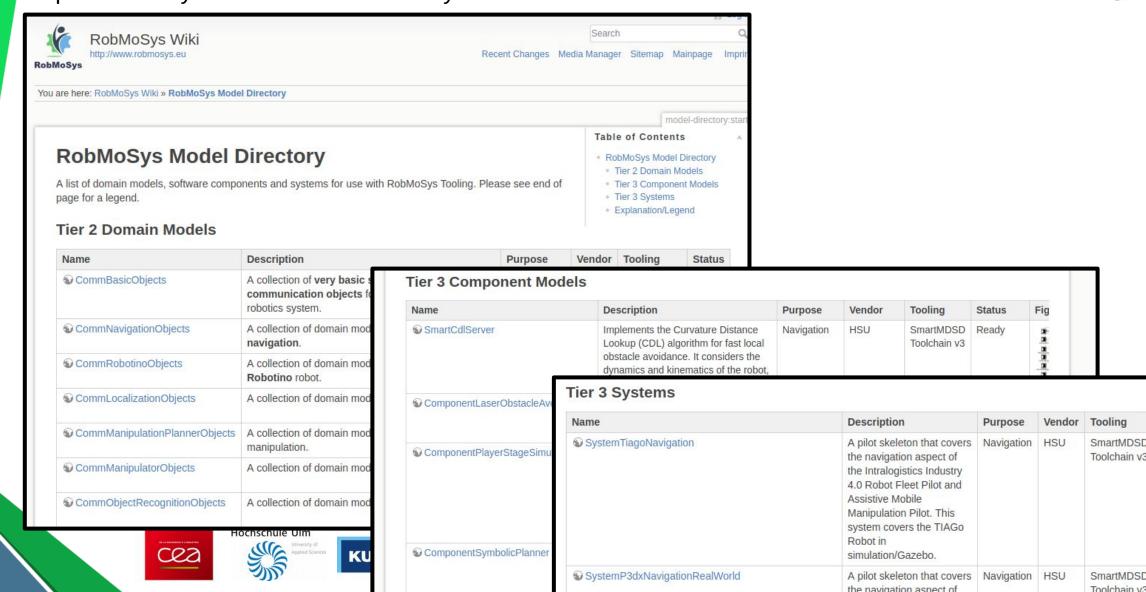 - be kept informed about major milestones and activities

- **RobMoSys Wiki => https://www.robmosys.eu/wiki**
  - first reference for in-depth information about the approach etc.
  - additional content to reflect the current state of the overall big picture and the according available baseline follows during the course of the preparation of the Open Call 2
  - additional content will also make it easier to find role specific / interest specific information

- **Discourse Platform => https://discourse.robmosys.eu**
  - the community platform to talk about models, tools, software for robotics, just get involved

- **Try it out**
  - tooling, building blocks, simulation, real robots, ..

Follow up on discourse.robmosys.eu

RobMoSys Modeling Directory
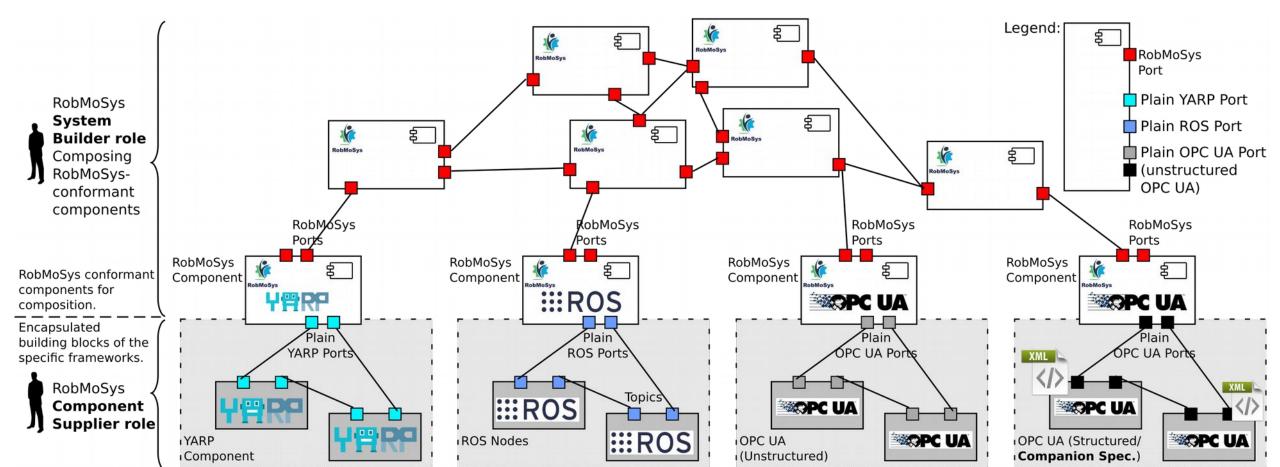
https://robmosys.eu/wiki/model-directory:start

Mixed-Port Components
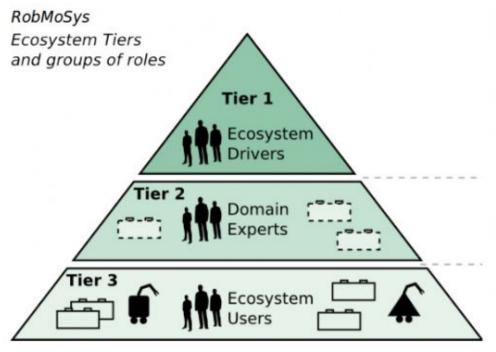
RobMoSys Ecosystem Organization:
Analogy with the PC Domain

RobMoSys

RobMoSys Ecosystem Tiers and groups of roles

Tier 1 — Ecosystem Drivers

Tier 2 — Domain Experts

Tier 3 — Ecosystem Users

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.
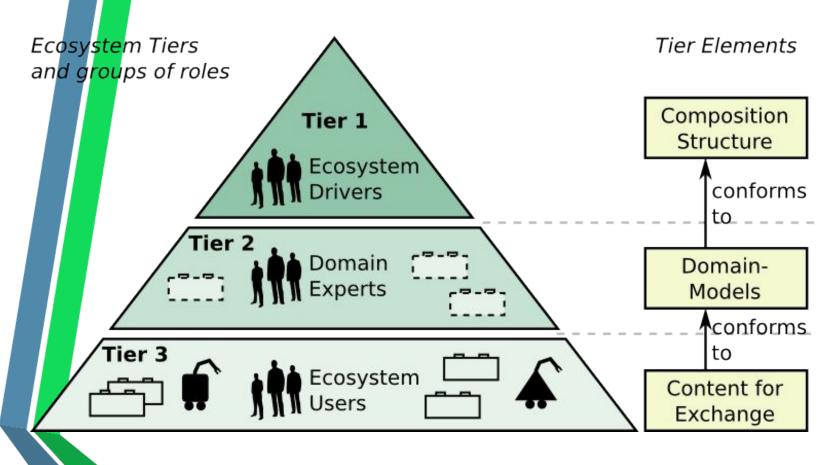
Examples of Robotics:

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.

RobMoSys Ecosystem Organization

Ecosystem Tiers and groups of roles

Tier 1 — Ecosystem Drivers

Tier 2 — Domain Experts

Tier 3 — Ecosystem Users

Tier Elements

Composition Structure

conforms to

Domain-Models

conforms to

Content for Exchange

RobMoSys envisions a robotics **business ecosystem** in which a large number of loosely interconnected participants depend on each other for their mutual effectiveness and individual success. The **modeling foundation guidelines** and the meta-*-model structures are driven by the needs of the typical tiers of an ecosystem and the needs of their stakeholders. The different **tiers are arranged along levels of abstractions**.

See: http://robmosys.eu/wiki/general_principles:ecosystem:start

RobMoSys Ecosystem Organization

- **Tier 1:** structures the ecosystem in general for robotics. It is shaped by the drivers of the ecosystem that define an overall composition structure which enables composition and which the lower tiers conform to (similar to, for example, the ecosystem of the Debian GNU/Linux OS and its structures). Tier 1 is shaped by few representative experts for ecosystems and composition. This is kick-started by the RobMoSys project.

    – Structures defined on Tier 1 can be compared to structures that are defined for the PC industry. The personal computer market is based on stable interfaces that change only slowly but allow for parts changing rapidly since the way parts interact can last longer than the parts themselves and there is a huge amount of cooperating and competing players involved. This resulted in a tremendous offer of composable systems and components.

- **Tier 2:** conforms to these foundations, structuring the particular domains within robotics and is shaped by the experts of these domains, for example, object recognition, manipulation, or SLAM. Tier 2 is shaped by representatives of the individual sub-domains in robotics.

- **Tier 3** conforms to the domain-structures of Tier 2 to supply and to use content. Here are the main "users" of the ecosystem, for example component suppliers and system builders. The number of users and contributors is significantly larger than on the above tiers as everyone contributing or using a building block is located at this tier.

Digital Data Sheet

Digital Data Sheet

Digital Data Sheet

RDF, Ontologies, ...

Documentation for humans

Tooling Interoperability

Support of the SmartMDSD Toolchain:

e.g. ecore meta-model for Component definition

Support of the SmartMDSD Toolchain:

Support of the SmartMDSD Toolchain:


```
runtime-oxygen-tc-v3.4 - CommNavigationObjects/model/CommNavigationObjects.skills - Eclipse Platform
File  Edit  Source  Refactor  Navigate  Search  Project  Model Converters  SmartMDSD  Run  Window  Help
```

Package Explorer

- CommBasicObjects
- CommLocalizationObjects
- ▼ CommNavigationObjects
  - ▶ JRE System Library [java-8-openjdk-amd64]
  - ▼ model
    - CommNavigationObjects.modes
    - CommNavigationObjects.parameters
    - CommNavigationObjects.services
    - CommNavigationObjects.skills
    - CommNavigationObjects.types
  - ▶ opcua
  - ▶ smartsoft
- ▶ CommRobotinoObjects
- ▶ CommTrackingObjects
- ▶ ComponentFestoMPSDocking
- ▶ ComponentFileMover
- ▶ ComponentFileProvider
- ▶ ComponentKB
- ▶ ComponentNavigationPlanner
- ▶ ComponentPathNavigationClient
- ▶ ComponentPurePursuitNavigation
- ▶ ComponentRobotinoBatteryChargerDocking
- ▶ ComponentRobotinoConveyerBeltServer_OPCU
- ▶ ComponentRobotinoIRServer
- ▶ ComponentSimpleKB
- ▶ ComponentTCLSequencer

CommNavigationObjects.skills ⊠   SmartCdlServer.skillRealization

```
SkillDefinitionRepository CommNavigationObjects {

    SkillDefinitionSet MovementSkills {

        /*
         * approach location (id, resolved using knowledge-base)
         */
        SkillDefinition moverobot {
            in {
                location : Int32
            }
            results {
                ERROR value = "UNKNOWN LOCATION";
                ERROR value = "ROBOT BLOCKED";
                SUCCESS value = "OK";
                SUCCESS value = "";
            }
        }


        /*
         * rotate the robot according to the locations setup (id, resolved using knowledge-base)
         */
        SkillDefinition orientaterobot{
            in {
                location : Int32
            }
            results {
                ERROR value = "UNKNOWN LOCATION";
                ERROR value = "ROBOT BLOCKED";
                SUCCESS value = "OK";
                SUCCESS value = "";
            }
        }
    }
}
```

CommNavigationObjects.skills - CommNavigationObjects/model

Support of the SmartMDSD Toolchain:

Support of the SmartMDSD Toolchain:

**Realization of Skills
Tier 3 (Component Developer)**

Support of the SmartMDSD Toolchain:

Support of the SmartMDSD Toolchain: