RobMoSys

# H2020—ICT—732410

# RobMoSys

## COMPOSABLE MODELS AND SOFTWARE FOR ROBOTICS SYSTEMS

## DELIVERABLE D6.6:
## REPORTS OF EXPERTS WORKSHOPS – M30

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# Executive Summary

This report summarizes the content of the second Expert Workshop held in Frankfurt the 8th-9th of October 2018.

This is the second workshop of a series of Expert Workshops we set along the project lifetime to gather all the possible insights and knowledge (mainly from near communities and industrial representatives) to (i) evaluate best-practices established in near and mature domains and (ii) identify current showstoppers that could arise in the robotics domain. This understanding is necessary to make sure that Open Calls will be prepared to provide concrete answers to the community, to finally overcome identified showstoppers and secure broad adoption.

This report summarizes the contribution of each expert: the content of the presentation the expert made during the workshop and presents the result of the discussions. Finally, we provide a synthesis of the expert's recommendations for RobMoSys.

# Content

# 1 Introduction

Transparency, openness, reactivity, and relevance are, among others, all very important behaviours for a project like RobMoSys, that depends to a large extent on contributions by the community, and acceptance of its outcomes by the same community and beyond. Hence, it is of the utmost importance that the Open Calls instrument of the project is used in the most effective way possible, and the strategy to realise this is to let the core team prepare the Calls together with a selected group of motivated and committed community members, each with a specific set of expertise and experience.

We call this group our "Tier 1" of community interaction, and we dedicate a part of the project efforts on getting these experts together in face-to-face workshops, and on getting their constructively critical comments on Call ideas, before we reach out to the whole community

Tier-1 Experts Workshops allow to systematically gather requirements and recommendations helping project team members to:

(i) Define the specifications of the Open Calls,
(ii) Monitor and assess the results of the Open Calls, and
(iii) Promote strategies for dissemination and exploitation.

This RobMoSys deliverable reports the second Tier-1 Experts workshop, held in Frankfurt the 8th-9th of October 2018, which is focused on gathering all the possible insights and knowledge to make sure that the Second Open Call will be prepared to provide concrete answers to the community, to finally overcome identified showstoppers and secure broad adoption.

For this second workshop, the Consortium invited experts, from relevant related domains, with a strong standardization, robotics open-source and industrial background, namely:

- Geoff Pegman (R.U. Robots),
- Victor Mayoral (Acutronic Robotics),
- Gurvinder Singh Virk (InnoTecUK),
- Eva Coscia (Holonix),
- Markus Klotzbücher

To prepare the workshop, each Expert discussed in an individual teleconference with the Consortium the general objectives of RobMoSys and the particular mission we were about to give to them. In order to set the context, the Consortium presented the following questionnaire:

***Sustainability.*** *We have an idea of how to make it sustainable via Eclipse and how to link to other communities like OPC UA…*

- *what do you think are key success factors for achieving sustainability and for achieving take-up?*
- *do you have positive or negative examples and do you have backed insights why these examples are positive / negative?*
- *what do you think can work / can not work for RobMoSys?*
- *what kinds of means do we need to ramp up?*

***Links to other communities***

- *how can we achieve a better link to outside communities? E.g. validation / verification, Industry 4.0, Mixed Criticality, Software Engineering, among others?*
- *what organisations (industrial, academic, RTO-based, etc.) that already offer community-access to relevant robotics platforms, would be of your strong preference to build synergies*

*with around Pilot cases?*
- *which are relevant other outside communities?*

***Involvement and take up of industry and step change***

- *how can we reach SMEs? What are their needs? How can we enable / support them to participate / to assist to ramp up the ecosystem?*
- *which of the RobMoSys technical user stories are the ones with the biggest wow-effect?*
- *which of these should we thus have addressed within RobMoSys?*
- *which of these are most interesting and most relevant for illustrating the step change?*
- *which aspects of the pilots are most suited to establish a link to industry?*
- *what metrics would you suggest to measure the success of the RobMoSys approach?*

***Digital data sheet***

- *how to describe building blocks with a digital data sheet such that you know what you get and how to use it?*
- *how to generate trust into descriptions, e.g. via testing, simulation, ...*
- *how to ramp up activities for a digital data sheet?*

The agenda of the workshop was as follows:

**Oct 8, 2018**

| | |
|---|---|
| 10:00 to 10:15 | Welcome |
| 10:15 to 11:15 | **Session 1: RobMoSys Overview**<br>• Introduction to RobMoSys – H. Espinoza (CEA)<br>• Technical Vision and Current Status – C. Schlegel (HSU)<br>• Vision for Community Building – S. Bieller (EUnited) |
| 11:15 to 13:00 | **Session 2: Presentations by Tier-1 Experts**<br>Presentations from Experts, focused on the scope of the meeting: Industrial Applications and Community Building based on the experts unique insights and background. – Geoff Pegman (R.U. Robots), Victor Mayoral (Acutronic Robotics), Gurvinder Singh Virk (InnoTecUK), Eva Coscia (Holonix), Markus Klotzbücher |
| 13:00 to 14:00 | **LUNCH TIME** |
| 14:00 to 15:30 | **Session 3: Brainstorming**<br>Brainstorming and Structured Discussion about RobMoSys Industrial Applications and Community Building and how to improve the success of the Second Call – Chairs: C. Schlegel (HSU), H. Bruyninckx (KUL), H. Espinoza (CEA) |
| 15:30 to 16:00 | **BREAK** |
| 16:00 to 17:30 | **Session 4: Structured Contributions**<br>Team working to elaborate a structured document where each expert fills in his most relevant insights and statements – Chairs: C. Schlegel (HSU), H. Bruyninckx (KUL), H. Espinoza (CEA) |

**Oct 9, 2018**

| | |
|---|---|
| 9:00 to 9:30 | Summary of previous day feedback – C. Schlegel (HSU) |
| 9:30 to 10:30 | **Session 5a: Structured Contributions regarding RobMoSys Call II**<br>Team working to elaborate relevant insights and statements about the preparation of the second RobMoSys Call – Chairs: C. Schlegel (HSU), H. Bruyninckx (KUL) |
| 10:30 to 11:00 | **BREAK** |
| 11:00 to 12:30 | **Session 5b: Structured Contributions regarding RobMoSys Call II**<br>Continuation of team working to elaborate relevant insights and statements about the preparation of the second RobMoSys Call – Chairs: C. Schlegel (HSU), H. Bruyninckx (KUL) |
| 12:30 to 13:30 | **LUNCH TIME** |

As part of the brainstorming sessions during the workshop, a number of ideas have been highlighted (See Figure 1), which are used in this report to summarize their recommendations (see Section 3).

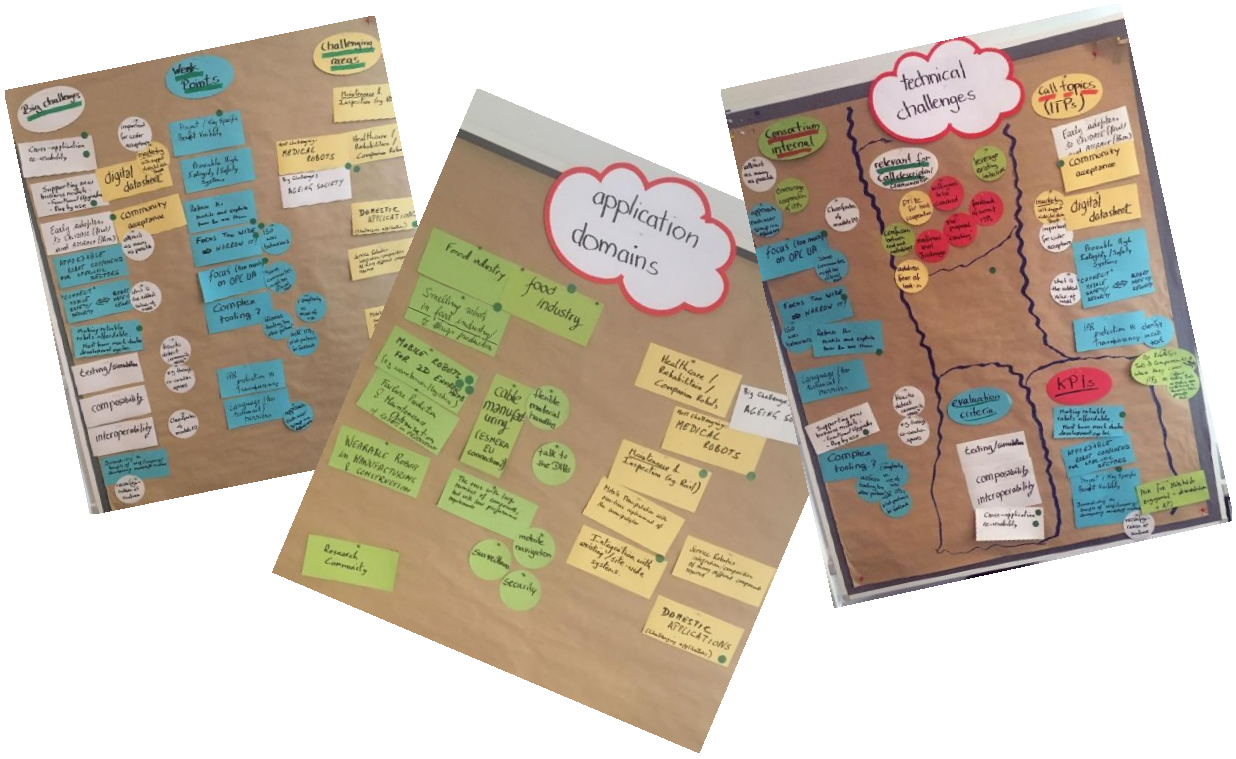


*Figure 1: Some brainstorming notes from the workshop.*

In the remaining sections of this report, we summarize the contribution of each expert: the content of the presentation the expert made during the workshop and presents the result of the discussions, in response to the questionnaire. Finally, we provide a synthesis of the expert's recommendations for RobMoSys.

# 2 Experts Contributions

This section summarizes the main inputs from Tier-1 experts from their presentations during the workshop. Detailed reports are provided in Annex A.

## 2.1 Geoff Pegman, Managing Director, R U Robots Limited

Geoff Pegman has a successful track record of developing new automation and robotics applications for over 30 years. He has considerable experience of developing hard real-time systems. Geoff spun out 7 hi-tech SMEs and has good links to robotics community and end-users.

Geoff presented a personal view on what should be the key success factors for RobMoSys. These are:

- Demonstration of reliability in hard use cases, in particular in realistic scenarios.
- Good dissemination on capabilities and ease of use
- Take-up, particularly by students
- Key lead customers, such as for example Aerospace or Medical
- Clear benefits statement
- Accessible repository
- Realistic license terms

He recommended to establish strong links with trade bodies and ERF. He also recommended to define first high level challenges and to build a co-creation space with the robotics community.

In addition, Geoff focused on identifying the SME needs the RobMoSys consortium must focus. Regarding end user SMEs (such as integrators), he mentioned that they could not care less about technologies and they need robust and easy to use flexible tools and systems. With regard to developer SMEs (such as robotic software developers), they need high availability of functionality and components, stability of the software and tool assets, requirements traceability, ease of use as well, and to get cost effective solutions.

Important recommendations by Geoff addressed how to reach SMEs. This includes to look for large RobMoSys end users, since they advocate for more users and start a multiplying effect. Geoff suggested to search incubators and accelerators for RobMoSys early adoption and to be involved in key DIHs (Digital Innovation Hubs).

As part of the wow-factor aspects, he proposed to focus on robotics Manipulation functionalities, safe and reliable human-robot collaboration (since it has many open issues MDE can improve) and target high application flexibility (real-time edit and build of designs).

Finally, regarding the digital Data Sheet concept, he suggested to create lots of use case examples, and address in particular timing requirements.

## 2.2 Victor Mayoral, CTO, Acutronics

Victor Mayoral Vilches works as CTO at Acutronic Robotics, a branch of the Swiss company. He is also a co-founder and advisor at Alias Robotics in Spain. As member of the Spanish National Robotics Committee, Victor Vilches is experienced in robotics and AI.

Victor focused his presentation on specific technical concepts of particular interest for RobMoSys related to system integration and modularity in robotics using ROS.

He argues that while many approaches (middleware and MDE approaches) already deal with best practices in software engineering, when we come with system integration, new problems arise beyond programming. His team use modularity as the core concept to address system integration.

Figure 2 describes the main principle advocated by Victor.

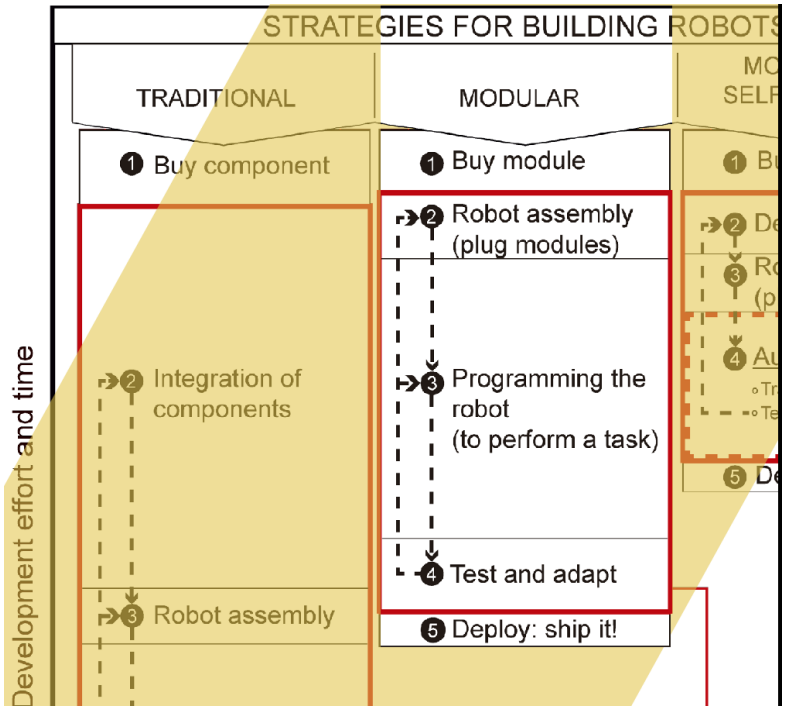


*Figure 2: Modular approach for building robots promoted by Acutronic Robotics.*

Victor argues that modular robots promise interoperability and ease of re-purposing. When followed, the integration effort is removed and the critical section reduced significantly. However, although the process of building robots, and particularly, the integration of new robot modules is simplified, the task of programming robots remains cumbersome. New modules, although interoperate, need to be introduced in the logic of the system manually. This implies that for each module addition or modification, a complete review of the logic that governs the behaviour of such robot will need to happen. In other words, the adaptation capabilities of these systems are still limited.

Further information about Acutronic work on modular robotics can be found in:

[1] Mayoral, V., Kojcev, R., Etxezarreta, N., Hernández, A., & Zamalloa, I. (2018). Towards self-adaptable robots: from programming to training machines. arXiv preprint arXiv: 1802.04082. https://arxiv.org/pdf/ 1802.04082.pdf

[2] Mayoral, V., Kojcev, R., Hernández, A., Zamalloa, I., Bilbao, A.. (2018, August).Modular And Self-Adaptable (MASA) strategy for building robots. In Adaptive Hardware and Systems (AHS), 2018 NASA/ ESA Conference.

Acutronic has been working in the evaluation of ROS 2.0 communications for real-time robotic applications. They have measured the end-to-end latencies of ROS 2.0 communications using different DDS middleware implementations in different stress conditions. The results showed that a proper real-time configuration of the ROS 2.0 framework and DDS threads reduces greatly the jitter and worst case latencies. Based on their results, we conclude that it seems possible to achieve firm and soft real-time Ethernet communications with mixed-critical traffic by using the Linux Network Stack but not hard real-time due to the observed limitations. In future work, they will evaluate several methods to limit the network and CPU usage. Also, they will evaluate the impact of non-critical traffic from another ROS 2.0 node in the same process or from the same node.

Further information on this work can be found in the following papers:

[3] Gutiérrez, C. S. V., Juan, L. U. S., Ugarte, I. Z., & Vilches, V. M. (2018). Time-Sensitive Networking for robotics. arXiv preprint arXiv:1804.07643.

[4] Gutiérrez, C. S. V., Juan, L. U. S., Ugarte, I. Z., & Vilches, V. M. (2018). Real-time Linux communications: an evaluation of the Linux communication stack for real-time robotic applications. arXiv preprint arXiv:1808.10821.

[5] Gutiérrez, C. S. V., Juan, L. U. S., Ugarte, I. Z., & Vilches, V. M. (2018). Towards a distributed and real-time framework for robots: Evaluation of ROS 2.0 communications for real-time robotic applications. arXiv preprint arXiv:1809.02595.

[6] Gutiérrez, C. S. V., Juan, L. U. S., Ugarte, I. Z., Goenaga, I. M., Kirschgens, L. A., & Vilches, V. M. (2018). Time Synchronization in modular collaborative robots. arXiv preprint arXiv: 1809.07295.

As a conclusion, Victor strongly encourages to use modular/compositional approaches to enable easy system integrations tasks and the use of ROS 2.0 as a main enabler to achieve real-time communications. Part of this work is being developed in other initiatives: ROS 2 working groups, and EU projects: micro-ROS and the HRIM project (ROSin's Focused Technical Project - FTP), in which Victor participates.

## 2.3 Gurvinder Singh Virk, Technical Director, InnoTecUK

Gurvinder Singh Virk has an extensive leadership experience in robotics industry and academy. This includes 30+ years R&D experience and major UK national and international collaborations. He is coordinator of the EC Network on Excellence on Climbing and walking robots for 10 years. He also has a major role in robot standardization (ISO/IEC and Europe): ISO TC299/ WG2 Chairman: Personal care robot safety, 2006-2016; IEC SC62A & ISO TC299 JWG5 Chairman: Medical robot safety; ISO TC299/ WG6 Chairman: Modularity of service robots; ISO TC299/ SG1 Chairman: Gaps and structure, 2017; euRobotics Topic Group Standardisation Coordinator for H2020.

Gurvinder started by summarizing the core aspects he deem RobMoSys should focus:

- Organising models, tools, and software components for maximizing inter-operability issues in (complex) robot systems
- Usage scenarios and concrete examples for safety analysis for composable scenarios
- Sustainability via realizing effective robot modularity methodology for improving affordability, ease in customisation
- Links to other stakeholder communities for real-world demonstrators, involvement and take up of industries.

He stressed the changing scenario in the robotics world from robots designed to operate in work-cells separated from humans for safety reasons, towards robots in hazardous environments, in close collaboration with humans, even in industrial applications (see Figure 3).

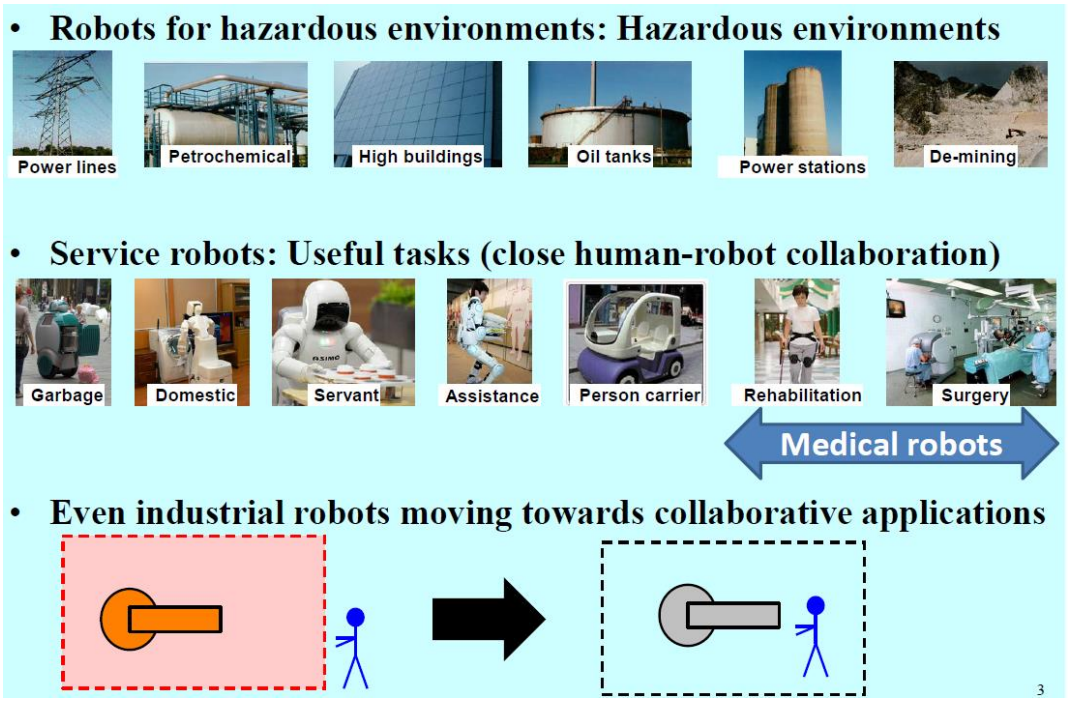


*Figure 3: Changing world of Robotics*

Among the different activities Gurvinder is involved, he mentioned WG6 on Modularity for Service Robots, as particular relevant for RobMoSys. The scope of this initiative is to formulate robot modularity guidelines from hardware and software perspectives. He advocates open modularity as the way forward. Closed supply chain markets have existed for many years (Figure 4). Modularity is able to define open basic principles such as inter-changeability at the interface ("open wires and closed boxes"); hardware connectivity and functionality; and software structuring, interfacing and overall operation. Open modularity improves the cost-efficiency balance, by enhancing rather than re-inventing (H/W and S/W), and by designing/assembling rather than designing/prototyping.

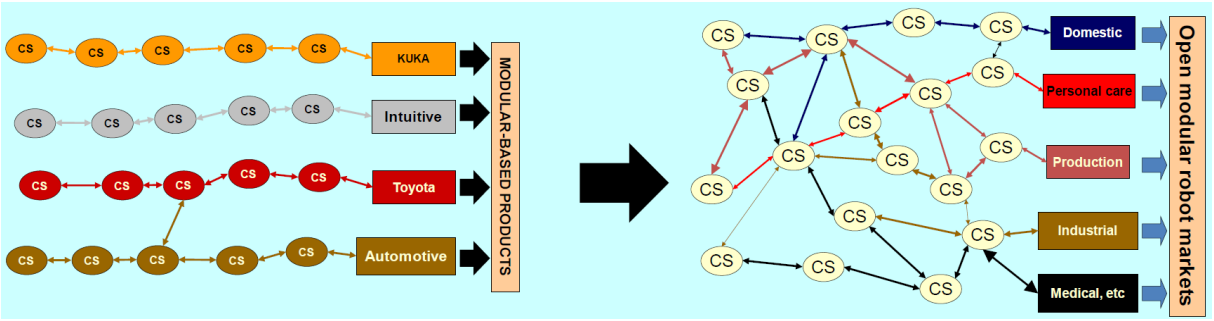


*Figure 4: Open modularity in Robotics*

## 2.4 Eva Coscia, R&I Director, Holonix s.r.l.

Eva Coscia works in European Research projects since 2000 (as technical responsible, project PM, coordinator…), in the domains of ICT for manufacturing, Smart factories, Smart Agriculture, using technologies such as IOT, CPS, Big Data, Industrie 4.0. She is interested on open innovation & co-creation methodologies and tools; Digital platforms for Industry. She was also consultant for DG-RESEARCH on e-Government/e-Procurement.

To create the RobMoSys ecosystem and make it self-sustainable, Eva recommended to:

- Make the access to RobMoSys assets simple: express in easy language what the platform offers; by intuitive matchmaking
- Start from the business model
    - Selling points for all roles in the value chain
    - Clarify who are the: the owners of platforms who control their intellectual property and governance; providers who serve as the platforms' interface with users; producers who create their offerings; and consumers who use those offerings
- Engage early adopters (beside the OC winners?)and refine the business modes based on their feedback
- Create success stories out of the Open Calls experiments

She provided some positive examples :

- FI-WARE community: catalogue of components, domain agnostic, maintained by a community
- Negative: not all GEs having the same quality; certification mechanism missing

Eva proposed some kinds of means to ramp up:

- Adopters
- Working matchmaking between offer and demand (see example in slides presented at European Robotics Forum 2017, Edinburgh
- WOW Pilots; real application cases; with quantification of cost and time for set up

She proposed some links to other communities:

- EFFRA
- Connected factories_ https://www.effra.eu/connectedfactories. The ConnectedFactories project establishes a structured overview of available and upcoming technological approaches and best practices. The project identifies present and future needs, as well as challenges, of the manufacturing industries.
- i4MS – Horse project
- Identify principles and approaches that can be sold outside the robotics domains (e.g.: certification, data sheets for component description, predictability of failures on monitored assets)

Other links:

- ECSEL: Electronic Components and Systems (PPP)
- Digitising European Industry (DEI): https://ec.europa.eu/futurium/en/blog/digitising-european-industry-what-going
- Digital Industrial Platforms:
- National intiatives and DIHs

Eva suggested to approach SMEs by means of:

- Needs: reduce the «customisation» time/effort; quantify the benefits
- Main obstacles: cost, complexity&skills, trust
- Other barriers: IPR protection, data sovereignty, mistrust («what comes from other sectors, cannot fit my needs»,

Finally, she suggested to focus on the following robotics applications:

- Human-Robot cooperation
- Failure prediction; Maintenance optimisation

## 2.5 Markus Klotzbücher, Freelancer in Robotics.

Markus is a freelancing Software Architect & Developer with background in embedded, distributed and real-time systems, as well as on DSLs for coordination of real-time robots. He was a Platform Manager and Team lead Embedded Software at Kistler Instrumente, Winterthur. He has a strong background with the uMF micro modelling framework and microblx function blocks for robotics.

Markus described the Yocto project launched in 2010 as a typical example of sustainability and take up. This project provides interoperable tools, metadata, and processes that enable the rapid, repeatable development of Linux-based embedded systems. In 2018, this project is actively developed, widely used, backed (and funded) by numerous industrial players, and with a strong community. What did Yocto get right?

The main success factors for sustainability of Yocto are:

- It provides added value to each role
- It lowers the entry barrier
- It has high quality documentation
- It limits the (perceived) lock in, GUIs optional
- It has a strong technical lead

This was sufficient to build a user community!

To get sustainability, Yocto:

- Support paying memberships
- It is part of Linux foundation
- It has full time core developers ("evangelists")

Markus believes these success factors can be applied to RobMoSys. In particular, he consider that RobMoSys has the following strengths:

- Well defined vision and goals
- Good understanding of mission and stakeholders
- First tools in place, more on the way
- Added value will be shown via pilot cases

Markus observes that this strengths address the managers, but it must also convince the "boots on the ground".

More concretely, he thinks that RobMoSys must focus on the following aspects to improve take up:

- The project must make clear where are the models, and what can users do with them.
- RobMoSys should differentiate project vs. product marketing
- For instance, he suggests to create: http://models.robmosys.eu as an entry point for potential users, ramp up action for digital data-sheet and simulation and testing results (focused on improving trust).
- RobMoSys must provide a quickstart: *demonstrate* (not illustrate!) value to user in 15 minutes on own robot. For instance, create a biggest "wow" example on system composition out of existing components and consistency checks. Another example is to improve attractive quality: such as validation of non-functional properties.
- The project must provide a strong communication platform (ML).
- RobMoSys should support the emergence of lead modeller(s)

To improve RobMoSys sustainability, Markus recommends to:

- Prioritize the creation of a RobMoSys community
- Become self-sustaining via paying members, with advisory board roles, prominent model

placement, and privileged access to testing and simulation infrastructure.
- Reinforce a branding programme for "RobMoSys compliance".
- Ensure long-term participation of technical evangelists.

In addition, Markus provided the following recommendations:

- Aim for the industrial users
- Plug-fest to test composability and interoperability (and to bring the growing community together)
- Involve people from functional programming
- Visible roadmap for beyond the end-of the project
- Actively address risk of perceived and real lock-in.

# 3 Synthesis on Recommendations by Experts and Actions Taken

During the second Tier-1 Experts Workshop, the RobMoSys Consortium received very helpful feedback, which was used as key factors to build:

- The **Second Open Call** (Work Package WP5)
- The **Sustainability** Strategy (Work Packages WP6 and WP7)
- The Industrial **Take up** Strategy (Work Package WP7)

Table 1 shows the main expert recommendations and actions taken by the RobMoSys Consortium. Please note that many of the actions are the outcome of this workshop but also of other discussion meetings inside the RobMoSys consortium.

*Table 1: Recommendations by Tier-1 Experts and Actions Taken*

| Recommendations | Actions |
|---|---|
| **Early Adoption**<br><br>RobMoSys must focus on **early adoption**. The goal is to validate and attract industrial companies. This must be accompanied by a strategy to lower the entry barrier. The consortium must focused on engaging the community by providing a suitable environment for collaboration between new adopters and RobMoSys experts. | **Second Open Call**<br><br>• The consortium decided to create a specific Instrument for *RobMoSys Fast Adoption (Instrument #1).* With this instrument, RobMoSys wants to boost fast adoption of the RobMoSys approach in industry.<br>• We developed a description of the RobMoSys *Adoption Path*, which was published as an Annex of the Guide for Applicants.<br>• We stressed that we look for proposals joining us to demonstrate with *real industrial cases* their own industrial success story. |
| **Industry Standards**<br><br>RobMoSys must be strongly connected to current (de facto and de jury) **industry standards**. This includes ROS 2, OPC UA, robotics modularity (e.g., ISO CD 22166-1). The ability to link with this standards (via APIs, bridges, common technology) will improve | **Second Open Call**<br><br>• As part of Instrument #2 (Ecosystem Challenges), we called for projects answering to challenges in the areas of ROS 2 (Topic 1) and OPC UA (Topic 6). These includes the different recommendations by Tier-1 Experts<br>• We stressed the need to provide guidance for standards compliance inside the tools to be developed in this second round of projects (e.g. safety standards).<br>• The RobMoSys Digital Data Sheet concept (reinforced in |

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| RobMoSys take up opportunities. | the second open call) is part of the efforts to standardise component/module interoperability and transparency. |
| **Modularity and Compositionality**<br><br>Modularity and compositionality in robotics design bring a number of benefits for reuse, interoperability, reduced integration costs and complexity management. However, many issues have to be solved regarding real-time response, QoS, and harmonization/standardization of APIs. RobMoSys has a strong basis to support composable robotics development and must foster the consolidation of an ecosystem of tools facilitating ease integration from reusable components. | **Second Open Call**<br><br>• The second open call includes 3 relevant topics on composition: Topic 2 (Functional composition inside components); Topic 4 (System level predictability of properties, Navigation) and Topic 5 (System level predictability of properties, Manipulation).<br><br>**Take Up**<br><br>• One way to foster the compositional approach in industry is the Digital Data Sheet approach. We aim at creating a strategy to make an active use of the data sheet approach in real applications.<br><br>**Sustainability**<br><br>• A repository of Software Components and Models has been created, as a starting point to facilitate the reuse of RobMoSys-conformant artefacts. This will grow during the project life and beyond. |
| **System Safety Aspects**<br><br>All the Tier-1 experts concurred on the idea of focusing on safety and certification aspects. Safety is a system property and it's crucial for enabling robots to work in open spaces, interact with humans and to ensure industrial deployment. | **Second Open Call**<br><br>• As part of Instrument #2 (Ecosystem Challenges), we called for projects answering to challenges in the area of System Safety (Topic 3).<br>• Compliance with standards and support to certification have been explicitly included in Topic 3.<br>• Human-robot collaboration is one of the Pilots made available in the second call for supporting safety and certification.<br><br>**Sustainability**<br><br>• We created a link with the COVR H2020 project (focused on safety for collaborative robotics). We jointly organized a workshop in France (January 10, 2019) to discuss cross-project topics on safety engineering and assessment. |
| **Community Building**<br><br>Community creation is a key factor for RobMoSys sustainability. Creating a community, RobMoSys must provide good access to project assets, with a strong communication infrastructure, and with a solid governance. | **Second Open Call**<br><br>• One of the key actions for community building in the second call was the creation of a new funding instrument: Innovation Expert Intake (Instrument #3). RobMoSys asks for experts to push innovation and strengthen the RobMoSys community.<br><br>**Sustainability**<br><br>• The consortium is currently working to define a community structure supported by euRobotics (conceptual aspects) and Eclipse foundation (technical assets). This will include most of Expert recommendations, including communication |

| | |
|---|---|
| | infrastructures, assets repository, and governance, collaboration with other initiatives such as ROSin or Seronet in Germany. Further information will be provided in WP6 and WP7. |
| **RobMoSys Awareness & Education**<br><br>One common key recommendation is the need to make RobMoSys awareness, training and demonstration material easily available and understandable by the community. | **Take Up**<br><br>• We created the RobMoSys Academy as a key entry point to awareness, training and demonstration material. This has been started as part of the RobMoSys webpage, but will evolve during the project as part of the RobMoSys community portal.<br>• The RobMoSys Academy is the set of structured resources providing guidance and support for RobMoSys stakeholders, including methodological guidance, tutorials, training, demonstrators and coaching. |
| **Links to Other Communities**<br><br>A number of initiatives have been listed to improve networking and take up. | **Take Up**<br><br>• As part of the community creation, we discussed with some robotics projects and initiatives: ROSin, Seronet, and organizations: euRobotics, Eclipse Foundation, to create a solid collaboration framework.<br>• We have an intensive technical exchange and collaboration with ROSin (CEA got funded a ROSin FTP, some ROSin partners applied to the second call). |

# Annex 1: Detailed Tier-1 Expert Recommendations

Please note that we are copying here the PDF versions of their reports.

## 3.1 Geoff Pegman, Managing Director, R U Robots Limited

### Sustainability we have an idea of how to make it sustainable via Eclipse and how to link to other communities like OPC UA…

**Key success factors for achieving sustainability and for achieving take-up?**

In answering this I have to differentiate between achieving take-up in academia and industry. While the first can lead to the second, it is not always the case. The reason for the difference is the emphasis on (cost of) original development versus ongoing support and maintenance. Academic usage is, typically, about demonstrating a principle and therefore the emphasis is on getting the applications up and running with the minimum cost. Usage will typically be limited to a restricted set of hardware, few variations and short run times. By contrast most industrial applications will put emphasis on the user experience over relatively long timescales, measured in terms of the cost of maintenance and support with, typically, applications being run on diverse hardware platforms or system configurations. Of course initial development costs are important but the developments are expected

In addition, the system has to be a complete solution, at least for some application areas (at first). It may be that the complete solution involves some or substantial non-Robmosys original elements, but these have to be brought into the Robmosys scheme in that case. It is far better to have a complete solution in a few application areas than a 80%-90% solution in most application areas.

Finally, for commercial success there needs, obviously, to be a vehicle to take the product / service to the market and provide the necessary services, i.e. a company that is committed to the commercial success of the approach with strong ties to the whole of the development team.

**Do you have positive or negative examples and do you have backed insights why these examples are positive / negative?**

In one of my early ventures we spent much time developing one of the first laser mapping systems. Initially the work , although plentiful, was difficult to scale as it involved sending teams of people to scan environments and then to convert those into CAD drawings involving a lot of operator skill. The breakthrough came with the decision to focus on one sector, that of petrochemical plants. This environment, mainly consisting of pipes, vessels and valves, albeit with large variety, enabled the process to be semi-automated with software tools for the majority of components. Not only did this speed up post-processing times but eventually allowed the software to be packaged and sold as a stand-alone package, hence achieving scale-up.

**What do you think can work / can not work for RobMoSys?**

The potential USP for RobMoSys is modular software incorporating real-time functionality. This is ideally suited to robot applications, particularly involving manipulators. This in turn will work best for B2B or professional robot situations. It will be of less value to domestic robot situations or, indeed, many mobile robot applications, particularly those involving relatively slow moving robots. There should also be caution about targeting the more general Cyber-Physical systems or automated

driving applications, with the latter already having many disparate software vendors with a vested interest in not following a common

**What kinds of means do we need to ramp up?**

In order to ramp up activity in the commercial sector using RobMoSys software, there needs firstly to be a delivery vehicle, i.e. a company or association which is dedicated to supply and supporting the software and ensuring that development continues in line with market requirements. It would also be beneficial to have a (large) lead customer or a lead customer group who would actively participate in providing feedback to develop the software. You would also need a clear benefits statement and clear and realistic licensing terms.

In order to obtain scale up of the activity you either need a nearly self-supporting software package and sales agents in key territories to sell worldwide or you would need to develop a franchise model for selling services.

## Links to other communities

**How can we achieve a better link to outside communities? E.g. validation / verification, Industry 4.0, Mixed Criticality, Software Engineering, among others?**

First-off you need to make people aware of the RobMoSys approach / software. This needs a multiple approach in terms of straight awareness material (targeted industrial workshops / conferences and trade-oriented magazines), links to educational establishments and direct approaches to key customers / customer groups.

A useful approach would be to establish an online resource hosting a User Group Forum, with specialised Application Focussed sections dealing with the application in specific industry areas.

**What organisations (industrial, academic, RTO-based, etc.) that already offer community-access to relevant robotics platforms, would be of your strong preference to build synergies with around Pilot cases?**

Most of the large RTO's (DTI, Fraunhofer, High Value Manufacturing Catapult, Tecnalia, etc) would provide good access to high technology users in their countries / regions. Persuading them to showcase the capabilities of RobMoSys and holding seminars in their premises would be good, particularly for accessing those interested in Industry 4.0. However, the establishment of many DIHs relevant to Robotics also provides significant opportunities for RobMoSys if alliances can be made.

**Which are relevant other outside communities?**

Other outside communities with relevance and influence would include learned societies like IEEE and IET, Industrial Associations such as VDMA and robotics or robotics-related associations such as euRobotics and EUnited.

## Involvement and take up of industry and step change

**How can we reach SMEs? What are their needs? How can we enable / support them to participate / to assist to ramp up the ecosystem?**

SMEs are difficult to reach. However, high technology SMEs (the presumed likely customers for

RobMoSys) are somewhat easier than the vast majority of SMEs. Raising awareness is through the measures described above.

The primary requirements for a software tool by a typical SME are:

- Functionailty / component availability
- Stability
- Requirments traceability
- Ease of use
- Cost effectiveness

**Which of the RobMoSys technical user stories are the ones with the biggest wow-effect?**

The user stories presented on the website are technical in nature. While these are important underpinnings, real user stories should be presented based around applications that illustrate the use of the technical benefits of RobMoSys.

Nevertheless, the technical features which potentially have the biggest wow factor are:

- Reduction in development time
- Shorter time to market
- Reduced costs (although this will be discounted as everyone CLAIMS this)
- Certifiable systems

**Which of these should we thus have addressed within RobMoSys?**

All of the above plus re-usability

**Which of these are most interesting and most relevant for illustrating the step change?**

Guaranteed certifiability

**Which aspects of the pilots are most suited to establish a link to industry?**

Human Robot Collaboration is very high in terms of industries awareness and emerging needs, particularly in areas that have been resistant to robotics. So both the Assembly collaboration and the assistive Mobile Manipulation would be good for attracting industry interest.

**What metrics would you suggest to measure the success of the RobMoSys approach?**

- Speed of development
- Development effort
- Reconfiguration time for new product / process
- Percentage of shared code / modules between different Pilots and perhaps even sub-systems.

## Digital data sheet

**How to describe building blocks with a digital data sheet such that you know what you get and how to use it?**

The digital data sheets should contain (short) description of their use, applicability and restrictions.

They should also contain a guide to their use and, particularly, configuration.

It would also be highly desirable to have some application sheets that detailed what building blocks went into the application and how they were put together (architecture).

Finally there should (obviously?) be user guide with extensive tutorials. This may be difficult to write in the early stages of the project.

**How to generate trust into descriptions, e.g. via testing, simulation, …**

- Real world testing
- Working Pilots (in realistic environments)

**How to ramp up activities for a digital data sheet?**

The best way I can think of for improving the content of digital data sheets is to have them as a specific topic within a user's forum.

## 3.2 Victor Mayoral, CTO, Acutronics

# 1 Summary of the presentation

The presentation titled as *"System integration and modularity in robotics using ROS"* provided insight and perspective on how robots powered by the Robot Operating System (ROS)[1] are being built and used in industry. Throughout the presentation, it was highlighted that system integration is one of the tasks that consumes the most resources in robotics. ROS already addresses many of the programming needs, however, system integration goes beyond programming robots. The presentation introduced how models such as the Hardware Robot Information Model (HRIM)[2], already in use and supported by other european initiatives (e.g. OFERA or ROSin) simplify the integration process. In particular, and as part of Acutronic Robotics' current efforts, Víctor shared the importance of modularity in the system integration effort[3] and the hardware-oriented focus that they currently have.

The presentation justified the value of modularity and introduced some of the challenges that come with it. Mainly, the need of a real-time capable link layer[4], a real-time capable networking stack[5], a real-time framework for robots[6] and time synchronization issues in robotics[7].

The presentation finished with some remarks about future work and existing solutions to deliver modularity.

# 2 Answers to proposed questions

## 2.1 Sustainability we have an idea of how to make it sustainable via Eclipse and how to link to other communities like OPC UA...

### 2.1.1 what do you think are key success factors for achieving sustainability and for achieving take-up?

The core ideas of RobMoSys are of tremendous value for the robotics community. Specially the commitment to provide open source formal models for robotics with appropriate tooling. In order to achieve sustainability on such

results, it's recommended to stick to existing and growing standards in the field of robotics, not so much from a research perspective but more from a developers' and industry's perspective. On this regard, ROS is the *de facto* standard and specially *ROS 2* is gaining industrial support and traction rapidly. From the analysis and discussions of the material of the project, it's essential to look at how tooling (specially lower end communication layers such as the OPC UA abstractions) could be integrated within the ROS ecosystem.

Looking at the existing ROS community, it is rather uncommon to use Eclipse for development purposes. On this regard, supporting educational actions that involve the usage of Eclipse in the robot application development process is recommended.

### 2.1.2 do you have positive or negative examples and do you have backed insights why these examples are positive / negative?

There're a few unknowns and strong critical views about OPC UA. Manufacturers are developing their own models based on particular needs which will result in interoperability conflicts. Recently, in a robotics conference, RTI's representatives pointed out that there's little substance behind what's happening at OPC UA. However, they announced[1] a bridge between DDS and OPC UA which will facilitate interoperability among systems.

On the other hand, there're ongoing efforts to introduce OPC UA serial protocols in the communication middleware layers of ROS 2 replacing the de facto DDS and allowing components to be programmed on top of OPC UA layers directly while maintaining client-level API compatibility with the ROS ecosystem.

### 2.1.3 what do you think can work / can not work for RobMoSys?

It's seen very positively that the project aims for the professionalization of software development in robotics. Model-driven engineering seems indeed to be the right path for solving the problem of complex software development and compliance with standards. The proposed approach somewhat opposes to the one followed by communities and frameworks such as ROS or YARP, born research-oriented and later used in a variety of use cases due to their popularity in academia. The overall approach and proposal of RobMoSys is well understood, shared and required in the existing landscape of robotics. Specially for industry. Yet, when looking at the overall robotics community, given the popularity of other approaches to build software in robotics, less formal but more dynamic, direct stakeholders for RobMoSys should be identified in industry (which will demand a more formal and professional path). Actions to connect with other stakeholders (outside of industry) through small projects that explore joint approaches are recommended but shouldn't be a priority.

The current landscape of robotics is today still vertical and strictly connected to hardware. Robot manufacturers typically oppose to the value that an horizontal approach could bring. Both in hardware and in software. From the available

[1] https://www.rti.com/blog/announcing-the-opc-ua-dds-gateway-standard

content in the website and wiki, the project is presented *too focused* on software aspects. Almost no proper reference to underlying hardware is made, which undermines certain claims. Specially, that the *proposed approach is an enabler for (better) system integration*. The importance of hardware should be considered as a key aspect when building a community in robotics. Collaboration with other approaches focused on hardware models such as HRIM, already supported by other European projects and in close collaboration with industrial robot part manufacturers, is highly recommended.

From what was understood, an additional point of concern is the adoption of a particular robotics framework/middleware combination. In particular, SmartSoft as the robotics framework together with the underlying OPC UA middleware, has little community and will receive opposition from existing ones, mainly the ROS community. This reasoning comes from the following content available at the wiki[2]:

> **ROS is in very widespread use; why does RobMoSys not build upon ROS?** ROS is semantically not rich enough to apply it for composition in an ecosystem as it is envisioned in RobMoSys. RobMoSys can be used with ROS but the restrictions mentioned in "Can I use RobMoSys with ¡insert robotics framework here¿?" apply here, too.
>
> ROS, in line with its overall design philosophy, does not yet give enough structure in an appropriate format in order to better support separation of roles and separation of concerns. The minimally required structures are a sound software component model which has to be formalized for use in model-driven tools in order to support separation of concerns (e.g. to maintain semantics independently of the OS/middleware mapping), to assist the different roles in conforming to structures like component life-cycles and to reduce exposed complexity by systematic and computer-assisted management of variation points.

To some, the reasoning that has been provided here is incomplete or partially wrong. First, all the communication patterns described in the project[3] are supported in ROS. It's also argued that ROS does not maintain semantics independently of the OS/middleware. This is false, specially, ROS 2 was created to provide a solution for this[4]. Same applies to component life-cycles in ROS 2, described and discussed at http://design.ros2.org/articles/node_lifecycle.html.

While several points of the aforementioned quote are argued, it's true that ROS does not provide a *sound software component model* by default, neither is *formalized for use in model-driven tools*. The HRIM project aims to provide an answer for the first issue with special focus on hardware.

[2] https://robmosys.eu/wiki/faq

[3] https://robmosys.eu/wiki/modeling:metamodels:commpattern

[4] Refer to http://design.ros2.org/articles/why_ros2.html, http://design.ros2.org/articles/ros_on_dds.html and http://design.ros2.org/articles/ros_middleware_interface.html

RobMoSys could provide means to complement this effort and extends it with expertise on software component models and MDE techniques.

#### 2.1.4 what kinds of means do we need to ramp up?

It's recommended to establish close collaborations with exising and ongoing modularity standards. Specially the ongoing work at ISO/CD 22166-1[5].

Overall, throughout the discussion in Frankfurt, it was made obvious that eventually, *'all manufacturers will speak OPC UA'*. This will not happen unless specific effort is put into coordinating manufacturers appropriately. If the project desires such event to happen, it's recommended to take direct actions with a plurality of manufacturers in a similar fashion to what the HRIM project is doing for the ROS community.

Specific industry stakeholders should be identified and brought into the project to gain traction.

### 2.2 Links to other communities

#### 2.2.1 how can we achieve a better link to outside communities? E.g. validation / verification, Industry 4.0, Mixed Criticality, Software Engineering, among others?

ROSin project is achieving a certain degree of success on these topics. It's recommended to open a direct channel of conversations with them and adopt some of their Quality Assurance (QA) elements.

Among the outside communities, it's recommended to engage and establish collaborations with the ROS one given its size and popularity through actions that demonstrate the value of MDE in simple software development use cases.

#### 2.2.2 what organisations (industrial, academic, RTO-based, etc.) that already offer community-access to relevant robotics platforms, would be of your strong preference to build synergies with around Pilot cases?

As discussed above and according to the expert's opinion, the main stakeholders for the professionalization of software development are within industry. Particular focus on this area is recommended, leaving aside organizations operating in other areas of application (such as academy). Particular examples involve robot SMEs with a close contact with the system integration effort, typically operating as integrators.

#### 2.2.3 which are relevant other outside communities?

As highlighted above, the ROS (and ROS 2) communities should be engaged. Closely connected to the ROS community is also the Gazebo community (developed by the same organization).

[5] https://www.iso.org/standard/72715.html

## 2.3 Involvement and take up of industry and step change

### 2.3.1 how can we reach SMEs? What are their needs? How can we enable / support them to participate / to assist to ramp up the ecosystem?

A list of recommended actions is described below:

- support the Robot Operating System (ROS) as an additional robot framework
- support the Gazebo simulator in combination with different robot frameworks
- take actions to provide models and components that enable security and cybersecurity protections
- take actions to provide models and components that facilitate the safety certification process

### 2.3.2 what metrics would you suggest to measure the success of the RobMoSys approach?

- Number of SMEs that adopted the technical deliverables
- Number of users that downloaded the deliverables
- Correlation with existing technologies and communities in the robotics domain, specially with ROS community and software
- Actions performed towards QA
- Actions performed towards Security
- Actions performed towards Safety

## 2.4 Digital data sheet

### 2.4.1 how to describe building blocks with a digital data sheet such that you know what you get and how to use it?

A digital datasheet should contain the following properties:

- Composable, that is, modules should be able to contain sub modules and a variety of components.
- Machine-readable and easy to translate to a portable format for visualization (PDF ideally)
- Open source tooling to generate the digital datasheet
- Connection with simulation, Gazebo preferably

#### 2.4.2 how to generate trust into descriptions, e.g. via testing, simulation, ...

- Adopt QA approaches being followed at other projects (ROSin)
- Incentivate the use of a preferred and popular simulation platform, e.g. Gazebo

#### 2.4.3 how to ramp up activities for a digital data sheet?

- Support and fund companies with a track of records on any of the critical areas for the development of the digital datasheet
- Support and fund approaches that will make active use of such artifacts in real applications

# 3 Recommendations

Most of the recommendations have been provided in the sections above. A compilation of the most relevant is presented below:

- It's recommended to stick to existing and growing standards in the field of robotics, not so much from a research perspective but more from a developers' and industry's perspective. On this regard, ROS is the *de facto* standard and specially *ROS 2* is gaining industrial support and traction rapidly. From the analysis and discussions of the material of the project, it's essential to look at how tooling (specially lower end communication layers such as the OPC UA abstractions) could be integrated within the ROS ecosystem.
- In the expert's opinion and looking at the existing ROS community, it is not common to use Eclipse for development purposes. On this regard, supporting educational actions that involve the usage of Eclipse in the robot application development process is recommended.
- The overall approach and proposal of RobMoSys is well understood, shared and required in the existing landscape of robotics. Specially for industry. Yet, when looking at the project material, it is unclear whether the focus is on industrial tasks or not. Given the popularity of other approaches to build software in robotics, less formal but more dynamic, direct stakeholders for RobMoSys should be identified in industry (which will demand a more formal and professional path). It is recommended to focus on supporting identified targets in Industry. Actions to connect with other stakeholders (outside of industry) through small projects that explore joint approaches may be executed but shouldn't be a priority.
- From the available content in the website and wiki, the project is presented *too focused* on software aspects. Almost no proper reference to underlying hardware is made, which undermines certain claims. Specially, that the *proposed approach is an enabler for (better) system integration.* The importance of hardware should be considered as a key aspect when building a community in robotics. Collaboration with other approaches

focused on hardware models such as HRIM, already supported by other European projects and in close collaboration with industrial robot part manufacturers, is highly recommended.

- From what was understood, an additional point of concern is the adoption of a particular robotics framework/middleware combination while leaving aside others. In particular, SmartSoft as the robotics framework together with the underlying OPC UA middleware. To the best of the expert's knowledge, this combination, nowadays has still little community and will receive strong opposition from existing ones, mainly the ROS community. It's encouraged to consider other combinations (e.g. ROS/DDS) and engage them with small projects that port the same MDE concepts to these popular ecosystems.

# A Typos and errors in the wiki

- https://robmosys.eu/wiki/start: In this section, we feature early adopters of RobMoSys methodology, composition structures, or tooling.
- https://robmosys.eu/wiki/general_principles:pc_analogy:start: Configuration is like going to a ...

# References

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[2] I. Zamalloa, A. Hernandez, R. Kojcev, I. Muguruza, and V. Mayoral, "Hrim: the hardware robot information model," in *ISR 2018; 50th International Symposium on Robotics*. VDE, 2016, pp. 1–4.

[3] V. Mayoral, R. Kojcev, N. Etxezarreta, A. Hernández, and I. Zamalloa, "Towards self-adaptable robots: from programming to training machines," *arXiv preprint arXiv:1802.04082*, 2018.

[4] C. S. V. Gutiérrez, L. U. S. Juan, I. Z. Ugarte, and V. M. Vilches, "Time-sensitive networking for robotics," *arXiv preprint arXiv:1804.07643*, 2018.

[5] C. S. V. Gutiérrez, L. U. S. Juan, I. Z. Ugarte, and V. M. Vilches, "Real-time linux communications: an evaluation of the linux communication stack for real-time robotic applications," *arXiv preprint arXiv:1808.10821*, 2018.

[6] C. S. V. Gutiérrez, L. U. S. Juan, I. Z. Ugarte, I. M. Goenaga, L. A. Kirschgens, and V. M. Vilches, "Towards a distributed and real-time framework for robots: Evaluation of ros 2.0 communications for real-time robotic applications," *arXiv preprint arXiv:1809.02595*, 2018.

[7] C. S. V. Gutiérrez, L. U. S. Juan, I. Z. Ugarte *et al.*, "Time synchronization in modular collaborative robots," *arXiv preprint arXiv:1809.07295*, 2018.

## 3.3 Gurvinder Singh Virk, Technical Director, InnoTecUK

**Summary of GSV's presentation**

The presentation discussed the general area of robotics starting from its traditional roots in industrial manufacturing applications since the 1960s. The industrial robots are normally manipulator robots having great power and they operate at high speed and with great precision and dexterity to perform tasks such as spot welding, handling, assembling, machining, polishing, inspecting, palletizing, etc. As these robots have been very dangerous, they have be mainly designed to work in workcells separated physically from human to ensure humans are not harmed. The robot manufacturing workcells have been well defined environments in the past and good automation systems have been realised for a variety of manufacturing sectors. As technology has develop the situations have become more realistic and challenging.

Since the 1990s new applications for robots have been evolving. Main areas include the following:

- Mobile robots for hazardous environments or where human access is not possible. Application domain have comprised, nuclear, petrochemical, power stations, underwater, etc.
- Service robots for a wide variety of useful tasks in application domains and sectors where close human-robot collaboration is essential for the robot to perform its intended tasks
- Medical robots are carrying out a variety of medical procedures such as robot surgery and robotic rehabilitation.
- Even industrial robotics has been evolving towards close human-robot collaboration and wanting humans to cooperate with industrial robots.

The changing robot landscape has demanded new safety requirements to be formulated because the traditional robots were designed and regulated under the safety requirements presented in ISO 10218-1, -2 standards develop under a working group focussed on industrial robot safety. This led to the creation of several new working groups tasked with producing the new standards. The main working groups are as follows:

- WG1 on Robot Vocabulary (Soon-Geul Lee, Korea as Convenor) created in 2006
- WG7 on Personal care robot safety (GSVirk, now MO Tokhi, UK Convenor) created in 2006
- WG8 on Service robots (Seungbin Moon, Korea, chair) created in 2006
- IEC/ISO JWG9 (joint working group with SC62A) on Medical electrical equipment and systems using robotic technology (GS Virk, UK, Convenor) created in 2011
- WG10 Modularity for service robots (GS Virk, UK, Convenor) created in 2014
- JWG35 Medical robots for surgery (joint working group with SC62D) (M Brossoit, Canada, Convenor; Project leader: Kiyo Chenzei, AIST, Japan) created in 2014
- JWG36 Medical robots for rehabilitation (joint working group with SC62D) (M Brossoit, Canada, Convenor; Project leader: Burkhard Zimmerman, Hocoma, Switzerland) created in 2014
- SG1 on Gaps & structure (GS Virk, UK, (during 2017), Convenor now R Nelson-Shea, USA

The new groups are develop urgently needed safety, common vocabulary, performance and inter-operability standards. Safety standards tend to be the most important but the following robot standards have been published or are being formulated for the new domains:

- Industrial robots
  - Safety: ISO 10218-1:2011, Safety requirements for industrial robots: Robot
  - Safety: ISO 10218-2:2011, Robot systems and integration
  - Safety: ISO TS 15066:2016, Collaborative (industrial) robots
- Service robots
  - Safety: ISO 13482:2014, Safety requirements for personal care robots
  - Performance: ISO 18646-1:2016, Performance service robots – locomotion wheeled
  - Modularity: ISO CD 22166-1, Modularity for service robots

- Medical robots
- IEC TR 60601-4-1, MEE with DOA

The new standards are helping manufacturers design their robots meet the needs regulations but concerns about boundary issues and gaps of the various robot domains are growing as industrial robots are being used in service robot applications and vice versa. The boundary issues for medical and non-medical robot applications is also becoming an issue especially with the growing ageing concerns and how assisted daily living applications should be covered. A Study group has been set up to investigate gaps and structure issues on how ISO Tc299 should be organised to meet the emerging and future needs for robot standardisation.

A summary of Recommendations to RobMoSys by GS Virk

**How RobMoSys can be made sustainable**

As RobMoSys is aimed at developing model-based driven methods and tools for robotics it is essential to convince the community that the models available will be able to address the main issues in the various applications so that methods and tools can work to an acceptable level and there will be effective management of the interfaces between different robot domains as foreseen in the project aims. If this does not happen and there is insufficient available content for users, I fear the approach will not be accepted by users.

At present the technical aspects of the project is rather specialised and cannot be easily absorbed to comprehend the details. What seems to be promised is very ambitious and almost unbelievable when we consider the real low technology readiness level status of robots operating effectively in real-world scenarios. The expectation of the community needs to be managed effectively and hopes should not be raised too high without adequate justification.

It may make sense to limit the attention to a few key scenarios arising in various robot domains and ensure deep detailed content can be developed and demonstrated successfully. Such initial developments are probably best carried out by a few specialists (by the Solution developers and early adopters) so good Quality-of Service results are achieved and a sound methodology can be developed and disseminated. Some limited “other limited-ability users” such as industry adopters, supporters, etc., could be included for robustness testing of the tools.

A second (or even third) phase that is based on the community developing the content could then be adopted to increase the volume significantly so that coverage of real-world scenarios and domains which needs to be catered for to achieve overall success can be undertaken.

Breaking down the overall task into the “modules” and their “inter-operability requirements” requires deep insights which must be obtained via wide engagement with the stakeholder community for the results to be both comprehensive enough and also acceptable enough to a large enough sector of the community. If this does not happen the results could be both insignificant technically and also irrelevant to the vast community. Engagement with the community is essential for ensuring success of the project. Simply believing that the approach being adopted by RobMoSys is the best is not likely to be convincing to the stakeholders. The RobMoSys consortium has to focus more on the engagement with the community on what needs to be done and then then how it should be done. Hence the approach needs to be flexible enough to react to inputs from the community.

Key success factors has to be consistently positive feedback from the community and also that the community size that has engaged with RobMoSys is growing in size. This size can be gauged by number of persons, number of organisations and also the number of robot application domains and scenarios, etc that are included within the project and how these are growing with time.

Collaboration between researchers, end users and robot companies are needed to ensure the initial models, software and tools are sufficiently good for making convincing arguments and encouraging the growth in the size of the community that is engaged with the project. This size is most important as the latter stages of the project are approached and a community driven approach is to be followed. Only then can ideas of sustainability become a reality. Organising sustainability around commercially viable services based on open source models, software components and tools does not seem plausible at this stage.

Offering some effective tools and support to address wide range of research problems in robotics would be a good way to encourage engagement with a sufficient core of the community. The tools need to be versatile enough and allow "critical mass applications" be possible before being launched for the community driven phase to be initiated. It is essential that there is sufficient flexibility in the initial stages to allow tuning to meet real-world needs. If this flexibility is not present, it is likely that the methods will not be successful widely.

Ramping up is only really possible by ensuring the community takes on-board the concepts and drives the development in an open source based manner.

The channels seem to be well thought in the 4 levels of engagement (awareness, understanding, commitment and action). I would also include real-world challenges and perhaps competitions for these in some way to assess the good solutions from the not so good ones.

**Links to other communities**

It is clear RobMoSys need to link to several communities, namely researchers, end users and robot manufacturers to name a few. These could all be grouped by robot sector but the focus needs to be driven by ensuring realisation of robot products and hence the whole process needs to be driven by the end users. Regulation is also important for this and so ISO/IEC standardisation groups should be engaged with to ensure the overall needs are included.

In this respect it may be sensible to consider grouping robot applications loosely into the following three main regulatory sectors:

- Industrial robots: this sector of robotics is currently aiming to develop collaborative industrial robots hence the pilot cases ought to include these aspects.
- Service robots: The main service robots seem to be mobile manipulators and wearable exoskeletons; hence scenarios with these robot could be interesting to focus on.
- Medical robots: The main medical robots are surgery robots and rehabilitation robots; hence scenario covering some details for these types could be developed

It is important to define some key Pilot cases in each sector so that they will appeal to a significant portion of the robotics community. If this does not happen, when RobMoSYs event are held, the Pilot cases and other details need to be modified using feedback from those already engagement with the view to increase engagement. This process needs to be monitored continuously and adapted in real-time to ensure growth in engagement is guaranteed.

The method of engagement using the 4 levels of engagement, as foreseen in the project seem sensible as already stated but challenges and competitions could usefully be included.

**Digital data sheet**

Gathering inputs from the community in a structured manner is essential for adequately describing modules and their interoperability requirements. The use of specially design templates for the digital data sheets with detailed fields to capture the technical details is important. Designing such templates in not easy and requires time, effort and large test subjects so the fullest variability can be explored in

the design. Designing templates and using the templates needs to go hand-in-hand so the resulting templates are fit for purpose.

Exhaustive testing of the data sheets in a continuous manner is important so that at the end of the project, the community platform can run efficiently with no or minimal support.

As the plan is to try and join an existing community to increase likelihood of success in the sustainability, suitable communities should be identified early on and engaged with for synergies to be developed during the initial stages and RoMoSys does not end up "re-inventing the wheel" that no body wants.

### 3.4 Eva Coscia, R&I Director, Holonix s.r.l.

## Summary of the key points

Recently, the European Commission has started programs and initiatives to foster the creation and upscale of platforms offering digital services to the European industries and their ecosystems (i.e.: https://ec.europa.eu/futurium/en/blog/digitising-european-industry-what-going ). The objective is to boost the adoption of new technologies, lowering the barriers that usually SMEs face and thus make them more competitive and innovative in the European and International markets.

Designing, implementing and ensuring sustainability to digital platforms is a very complex task and consortia need a wide range of expertise to accomplish this mission. Therefore, it is important to look around at what other initiatives are doing, to learn from them and to create synergies

Platform in the robotic domains have for sure peculiar characteristics and have to overcome specific barriers, but there are experiences from other domains and technologies, such as:

- Manufacturing and the Industry4.0 movement
- Health (eHealth, Digital Health, and Smart Living environments)
- Agriculture and Food
- Transport and logistic
- Embedded and Critical Systems
- Systems of Systems

Moreover, there are topics and approaches, not specific of the robotics domain, that have to be explored also for RobMoSys, such as:

- **Standards**: to ensure interoperability of information, reusability and composability of components in complex systems.
- **Open Platforms**: how to develop platforms that are open and extensible, also thanks to the adoption of standards
- **Trust and reputation** creation methodologies and technologies
- **Open Innovation and co-creation** approaches adopted in many different sectors (historically adopted in Smart City, Smart Living, and recently in the Smart Manufacturing domains)
- **New Business Models** enabled by digital platforms

# Answers to proposed Questions

## SUSTAINABILITY

**Question 1:** what do you think are key success factors for achieving sustainability and for achieving take-up?

The sustainability of the platform is strongly based on the creation of the ecosystem around which define a strategy of incentives and services to make it self-sustainable.

To achieve the consolidation of a **critical mass of early adopters** it is necessary to make the access to the platform as simple as possible, to use an easy language to express what the platform offers. Once adopters enter the platform looking for a specific asset or service, the matchmaking between demand of the customer and offer of the platform should be as intuitive or automatic as possible. Customers should be guided in defining precisely what they are looking for, without any need of specific technological background: this is specifically relevant to attract the final end users of the RobMoSys platform, that are mainly SMEs looking for high level robotics-based solutions.

Early adopters in the case of RobMoSys could be initially the winners of the open calls. They should help creating, together with the other end users in the consortium, a set of **success stories** to present how the platform can be used and which are the impacts and benefits that any organisation, especially SMEs, but also developers, system integrators and other stakeholders, can receive from the adoption of the platform services.

The definition of a **business model** is crucial to plan a sustainability strategy: this starts from the identification of the selling points offered to each typology of stakeholder in the value chain that is addressed by the platform services. The business model should be refined with the support of early adopters, to revise the definition of exploitable assets matching the expectations of the platform customers.

Moreover, it is important to clarify the **roles** that should be involved in the commercial, post-project exploitation of the platform. The platform owner is who controls the intellectual property and is in charge of its governance. Platform providers are those ones who serve as the platforms' interface with users, which have the contact with the ecosystem. Platform producers are those ones who create the offerings; and finally the consumers are those ones who use those offerings.

The Digitising European Industry (DEI) initiative[1] of the European Commission is a concerted action to strengthen Europe's position in digital technologies and digital industrial platforms across value chains in industrial sectors. It released a report on

[1] https://ec.europa.eu/digital-single-market/en/policies/digitising-european-industry

"Digital Industrial Platforms", as result of the activities of the working groups tasked support the creation of next-generation digital platforms by defining possible next-generation platforms, reflecting on how building platforms should be approached on European level, and considering how existing and planned EU-wide, national, and/or regional platform development activities could contribute. The WG2 released a report on the analysis of the existing models of service platforms; it resulted in the distinction between Exchange Platform and Maker Platform. The first typology groups together platforms that are similar to marketplaces, with an offer of services to let demand meet the offer. In the second case, platform services support the development of new services, thus main stakeholders are developers and not consumers. Examples are reported in Figure 1.

RobMoSys should position itself in this schema and identify similarities to the existing platform, to borrow from them the business models and sustainability strategy.

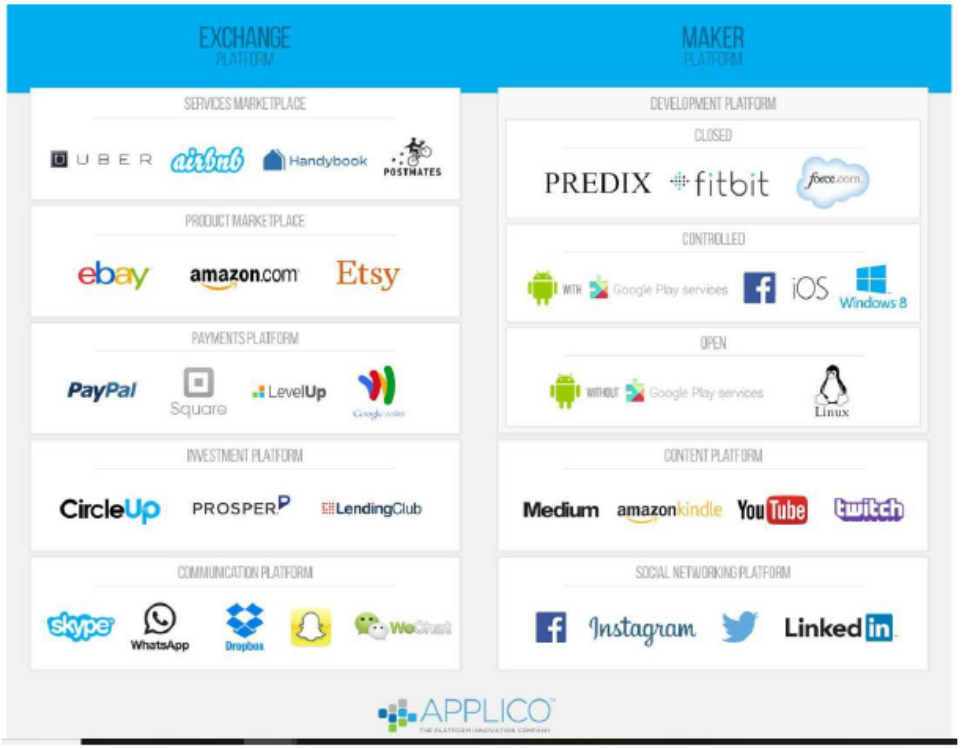


*Figure 1: Examples of Makers and Exchangers Platforms from the DIP report*

**Question 2:** do you have positive or negative examples and do you have backed insights why these examples are positive / negative?

An example could be the FI-WARE community, which offers a catalogue of components, that are domain agnostic, and are maintained by a community of developers. Most of these components are open source, but also commercial ones are offered. The main negative aspect is that not all these components have the same quality in terms of documentation, working functionalities and support. In that sense, the certification mechanism offered by RobMoSys could be a key advantage.

**Question 3:** what kinds of means do we need to ramp up?

The "chicken and egg problem" is that no stakeholder will ever adopt a platform that is a desert, with none or very few users and limited service offer. Thus, before entering a commercial phase, and within the duration of the project, it is important to leverage on end users in the consortium and winners of open calls, that are already motivated to use the platform, to attract other adopters, both promoting it inside their communities and domains, as well as by creating new services and nice stories to present the benefits of the platform.

The matchmaking between offer and demand should be presented in an intuitive way, for example through the story in the slides presented at European Robotics Forum 2017, Edinburgh.

The "Wow" effect can be achieved by presenting real application cases from the Pilots and from the expertiment of the open call winners, supported by quantification of the necessary effort and resource to replicate them, that is cost and time for set up.

## LINKS TO OTHER COMMUNITIES

**Question 1**: how can we achieve a better link to outside communities? E.g. validation / verification, Industry 4.0, Mixed Criticality, Software Engineering, among others?

There are initiatives that are already conducting activities concerning the development and adoption of digital platforms. They also have developed communities that could be also adopters of the RobMoSys platform.

For example:

- **EFFRA**: the European Factory of the Future Association, with a large community of stakeholders interested in promoting the adoption of the new technologies and methodologies to support the evolution of the European Manufacturing domain. EFFRA promotes research projects and creation of events across domains and technologies
- In particular, EFFRA launched the **Connected Factories** initiative project[2] to establish a structured overview of available and upcoming technological approaches and best practices for manufacturing platforms. The project identifies present and future needs, as well as challenges, of the manufacturing industries.
- **i4MS**[3] – and in particular the **Horse** project. I4MS (ICT Innovation for Manufacturing SMEs), is a European initiative supporting manufacturing SMEs and mid-caps in the widespread use of information and communication technologies (ICT) in their business operations. Robotics is one of the technologies addressed by the i4MS initiative. Beside the large community of stakeholders already created around i4MS, what the initiative could offer to RobMoSys are: examples of best practices defined to explain the adoption of

[2] https://www.effra.eu/connectedfactories
[3] https://i4ms.eu/

ICT technologies by SMEs and the obtained impact; Experience in launching and managing open calls (maybe possibility of promote the RobMoSys Open Calls through I4MS); example of catalogues of skills, competences and training material (under construction); examples of incentives, such as disruptors award, to gain attention around an initiative/project/platform and promote innovative contributions.

Before approaching these communities, RObMoSys should identify principles and approaches developed in the project that can be sold outside the robotics domains (e.g.: certification, data sheets for component description, predictability of failures on monitored assets)

**Question 2:** what organisations (industrial, academic, RTO-based, etc.) that already offer community-access to relevant robotics platforms, would be of your strong preference to build synergies with around Pilot cases?

As mentioned before, i4MS; that already offers access and promotion to the HORSE robotic project, could be an effective channel to promote the RobMoSys activities and give visibility to the Pilot cases

**Question 3:** which are relevant other outside communities?

Example of other communities to be addressed are:

- **ECSEL**: Electronic Components and Systems (PPP)
- **Digitising European Industry** (DEI): https://ec.europa.eu/futurium/en/blog/digitising-european-industry-what-going
- **National initiatives and DIHs**. In particular, the i4MS initiative has identified a network of DIHs at European Level, specialised on different topics, including Robotics (see Figure 2)

BRH - Belgrade Robotics Hub (Beogradski Robot Hub)
Robotics

iAsturias 4.0
Robotics, Cyber-physical system, Internet of things

Lithuanian robotic association
Robotics

CROBOHUB - Innovation Centre Nikola Tesla
Robotics

iMan Norte Hub - Digital Innovation Hub for Customer-Driven Manufacturing @ Norte
Robotics, Cloud-based HPC simulation, Cyber-Physical Systems, Internet of things.

Stam S.r.l.
Robotics

IndustryBrains
Robotics

C.R.E.A.T.E. - Consorzio di Ricerca per l'Energia, l'Automazione e le Tecnologie dell'Elettromagnetismo
Robotics

SmartIC Robotics
Robotics, Cyber-Physical Systems

*Figure 2: list of DIHs specialised on Robotics, from the i4MS portal*

## INVOLVEMENT AND TAKE UP OF INDUSTRY AND STEP CHANGE

**Question 1**: how can we reach SMEs? What are their needs? How can we enable / support them to participate / to assist to ramp up the ecosystem?

The identification of their main needs is a necessary step before trying to reach and engage SMEs. Due to the limitation in resources they can allocate to research and innovation activities, they are usually looking for solutions that have already been tested by other SMEs, that do not need extensive «customisation» time/effort. But first of all, they need to have indication about the benefits and quantification of the impact, to justify any investment they should make to adopt the new solutions. Thus examples of adoption from other SMEs should be accompanied by information such as: Which are the main steps to be implemented and how long dose they take? Which are the hw/sw requirements to introduce the new solution? Which are the necessary internal skills and competences? Which external support is necessary and who can offer it?

Offering access to non-sw resources could be an additional leverage: for example information about research centres, DIHs other entities that could support the adoption of new technologies or the integration within existing systems; training material; community services to open a dialogue with

Other barriers that could prevent the adoption from SMEs are: IPR protection (especially for developers contributing to the offer of the platform), data sovereignty (SMEs should be reassured about the usage of their data that is done when integrating the RobMoSys component to create new systems), mistrust (SMEs are prone to think «what comes from other sectors, cannot fit my needs»).

**Question 2**: which of the RobMoSys technical user stories are the ones with the biggest wow-effect?

**From the perspective of the manufacturing domain, the most interesting user stories are the ones offering solutions that enhance**

- Human-Robot cooperation
- Failure prediction of robots in production
- Maintenance optimisation of robots and their components, to reduce the costs of stopping production and assistance

## WHICH STRATEGY DO YOU RECOMMEND TO GET MORE COMMUNITY INVOLVEMENT?

A dissemination strategy has as main objective the promotion of RobMoSys results to the widest possible community, to attract early adopters of the platform (users of services and developers that contribute by developing new components).

The first promoters of these initiatives should be the RobMoSys partners in primis, that have networks which these adopters could come from.

As soon as the MVP (Minimum Viable Product) is ready, the industrial end users should work as testimonials to present the RobMoSys results, organising workshops and demos at regional/national or sector level. Since SMEs cannot afford to travel and spend time for attending dedicated events, the idea is to either make them virtual (webinars, videos, etc..) or to pair them with large events where SMEs should come not specifically for RobMoSys, Presence at international fairs with booth, stands and presentation conducted by partners could be exploited to attract the SMEs.

These dissemination activities should be customised for the different categories of potential stakeholders that RobMoSys addresses: final end users, sw developers, system integrators and even platform providers.

Specific messages and languages should be used to best attract each category of stakeholders.

The capillarity of dissemination could be supported by establishing cooperation with Regional/National initiatives and with DIHs operating at local level. Contacts with associations and clusters could be very effective as well.

## WHICH CHANNELS DO YOU RECOMMEND FOR DISSEMINATION?

Besides the partners' network, it is recommended to use the following channels:

- I4MS

- Industrial and sectorial fairs and events at National/Regional level
- Establish connection with the ERRIN [4]programme, identifying regional initiative of interest
- Living Labs, Innovation Hubs, and other initiatives for the promotion of new technologies adoption by SMEs
- Cooperation with other Robotics Institutions operating at National Level (e.g.: ITT in Italy, SSSA, Pisa in Italy, the CEA, Paris in France and BRL, Bristol in the United Kingdom)

# Summary of recommendations

A summary of Recommendations to RobMoSys (about 1-2 pages).

## RECOMMENDATION 1

**Attract adopters and contributions through stakeholder-specific messages**

RobMoSys can offer valuable results and services to many different stakeholders. Elaborate on the definition of their expectations, needs and potential contributions, for example using personas, could be helpful. Based on that, each category has a specific language and interest for specific valuable assets of RobMoSys; therefore, a unique message cannot work. If you want to attract end users SMEs, the message is definitely different from what you should communicate to system integrators, sw developers or hardware providers, for example.

Different communication strategies, contents and tools are required

## RECOMMENDATION 2

**Simplify adoption of the platform**

SMEs, especially in Europe, are strongly motivated to innovate to emerge and beat the competition. But they are limited in resources they can allocate. Thus the benefit they can gain must be clear and quantified. But even more important, things have to be as simple as possible, for each category of stakeholders: the ones who can contribute to the platform and use RobMoSys tools to implement new components, but also the SMEs that are interested in adopting the results and integrate them into existing solutions. Therefore examples, guidance, training are of outmost importance to encourage platform users.

## RECOMMENDATION 3

**Think from the beginning about the post-project phase**

Sustainability of digital platforms is a very complex issue and thus need to be addressed from the beginning of the platform development.

The underlying business model, starting from the identification of the valuable assets to be exploited and from the precise definition of target stakeholder, has to be defined in the early stages, as it influences the way the platform is designed and implemented, the dissemination activities and also the objectives of the Open Calls. Since platforms needs Business Models that are quite new and different from the ones traditionally adopted to support products, it is important to learn from others' experience in that domain. It is important to establish a continuous interaction and confrontation with end users, engaged in early validation, as well as with similar initiatives, to refine the business model and sustainability plans accordingly with the received feedback.

## RECOMMENDATION 4

### Look around and beyond robotics domain

RobMoSys is facing several challenges that are not specific of the robotics domain. Therefore it is important to identify problems and opportunities, methods and tools that are adopted in other domains to learn from what others are doing.

This will avoid the risk of elaborating strategies and solutions that could have been solved by others. Moreover, the innovation potential of RobMoSys could be improved by adopting solutions, approaches and methods and tools that traditionally belongs to other sectors and have not been experimented yet in the robotics domain.

### 3.5 Markus Klotzbücher, Freelancer in Robotics.

# 1 Introduction

The main tenor of the questions posed to the experts relate to how to achieve *sustainability*, *take up* and in a broader sense *impact*. Thus, this section focuses on answering the question

> what do you think are key success factors for achieving sustainability and for achieving take-up?

while deriving answers to further questions from this one.

To identify such success factors, it can be helpful to examine similar projects in terms of the success factors that contributed to sustainability and take-up. In the following the Yocto project [1] is used as such a running example. Yocto, started in 2010, develops tooling and processes to improve development of embedded Linux systems, but in addition fostered and grew a community of supporters and contributors. Today, this project can be considered successful by most standards, though this may not have been self-evident initially. Although goals and domain are certainly different from RobMoSys, the ideas of advancing the development methodology, developing supporting toolchains but also community building and industry involvement are surprisingly similar. Thus, examining the success factors for Yocto can provide some insights into what may also work for RobMoSys.

## 1.1 Take up

The following are main factors that contributed to the take up of Yocto. All of these are also applicable to RobMoSys, which is discussed in each paragraph.

### 1.1.1 Providing added value for each stakeholder

Yocto appealed to *manager/decision* maker type roles by offering the possibility to *reduce costs* by avoiding development and maintenance of own build tools. For *developers* Yocto promised taking care of a part (the build toolchain) that is frequently considered boring, thus permitting to focus on more interesting aspects of the development.

**Applicability to RobMoSys.** The theoretical benefits are clearly explained in the RobMoSys wiki (this will contribute to convincing the managers), yet it is essential to convince developer roles (function developer, system builder, ...) of the approach. One important way to achieve this is by demonstrating how the toolchain will simplify their day-to-day work. The most suitable user story to achieve this (and hence also producing the biggest wow-effect) is *composition of components*[1]. Preferably, the added value of the RobMoSys approach can be demonstrated with

[1] https://robmosys.eu/wiki/general_principles:user_stories#composition_of_components

a *quick-start* tutorial in a short amount of time (15 minutes). Moreover, I would recommend focusing on industrial users, since these will be generally more willing to prioritize benefits such as quality or development speed over personal toolchain preferences (see section **??**.

### 1.1.2 Lowering the entry barrier

A build system (not unlike a model driven engineering toolchain) is typically not a straightforward tool to use. Nevertheless to gain users, it is essential to quickly convince the primary users. Yocto achieves this by

- high quality documentation
- responsive support via mailing list
- making it easy to find and reuse existing build recipes

**Applicability to RobMoSys.** The first two points are rather obvious, but the third is where RobMoSys has most potential. When visiting the RobMoSys website, it currently not clear how to locate existing models or how to make available a new component. As such I would recommend realizing a (lightweight) web-platform (e.g. `http://models.robmosys.eu`) that allows searching for models and hosting new ones. For instance, the *OpenEmbedded Layer Index*[2] could serve as an inspiration.

### 1.1.3 Limiting the lock-in

Committing to a meta-build environment, even if open source, has a huge lock-in potential, as migrating to a alternative system will likely require a substantial effort. However, the backing by industry, the fact that the Yocto toolchain was based on the existing technologies (such as OpenEmbedded) and the rapidly emerging community helped overcome this potential impediment.

**Applicability to RobMoSys.** There is a risk that developers and decision makers are reluctant to commit to a toolchain developed in the context of an academic project for fear that its maintenance will subside after the project end.

To mitigate this risk, I would recommend addressing this question (e.g. in a FAQ) and making clear that these toolchains have been developed and maintained prior to RobMoSys and will continue to be developed after the project end. Moreover, providing a **visible roadmap** for beyond the project end will also help to address this fear. But the perhaps strongest counter-argument would be the forming of a community (even if at an early stage)!

[2] `https://layers.openembedded.org`

### 1.1.4 Mechanism vs. Policy

Even though graphical tools such as Eclipse are provided by Yocto, their use is optional for those users who prefer the command line. This was likely a critical success factor to win the embedded Linux developer community.

**Applicability to RobMoSys.** Likewise, there is a risk that the RobMoSys approach is rejected by parts of the robotics community not because of the underlying RobMoSys methodology, but on the more superficial reason that both of the reference toolchains are developed as GUI applications, opposed to command line tools. Even though this may seems absurd to a non-developer, it is hard to underestimate the relevance of this.

**Mitigation.** The distinction between methodology and toolchain should be explained and emphasized. There is no inherent reason that the RobMoSys approach is tied to a particular toolchain implementation philosophy. In the mid-/long term RobMoSys toolchain developers may consider defusing this potential rejection by separating their toolchains into graphical frontend and command-line tools.

### 1.1.5 Strong technical leadership

It could be argued that a large part of the Yocto success can be attributed to having a strong technical lead, who is visible and respected in the community and responsible for technical decisions.

**Applicability to RobMoSys.** It is suggested to clarify who can take over this role in RobMoSys and ideally how their participation can be ensured beyond the end of the project.

## 1.2 Sustainability

Yocto achieved sustainability through the following

- having built a community of users and contributors
- paying members to ensure funding
- full time development team to maintain and evolve
- backing via the Linux Foundation

**Applicability to RobMoSys.** Typically the precondition for achieving sustainability is the existence of a community. As such, establishing one should be the primary goal. Once this is achieved, users will be interested to support and fund the further existence. Paying member can be offered additional benefits such as access to test infrastructure, preferential placement of components on the web-platform or project advisory board positions.

# 2 Questions and Answers

## 2.1 Initial Questions

### 2.1.1 Sustainability

- *what do you think are key success factors for achieving sustainability and for achieving take-up?*
- *do you have positive or negative examples and do you have backed insights why these examples are positive / negative?*
- *what do you think can work / can not work for RobMoSys?*
- *what kinds of means do we need to ramp up?*

The key factor to achieve sustainability is *having* a community that is willing to contribute manpower and funding to maintain and further evolve tools and processes. As a positive example the Yocto project was introduced in section 1. As the scope of model driven engineering in robotics is vast, it is essential to focus on specific application domains and use-cases and to support these well. In my opinion, it would be most convincing to focus on supporting the system builder[3] role. To ramp up, as described in the previous section, it will be crucial to promote the RobMoSys toolchains, convince developer roles and support them once they start using the toolchains.

### 2.1.2 Links to other communities

- *how can we achieve a better link to outside communities? E.g. validation / verification, Industry 4.0, Mixed Criticality, Software Engineering, among others?*
- *what organisations (industrial, academic, RTO-based, etc.) that already offer community-access to relevant robotics platforms, would be of your strong preference to build synergies with around Pilot cases?*
- *which are relevant other outside communities?*

[3] https://robmosys.eu/wiki/general_principles:ecosystem:roles:system_builder

It is challenging to provide a generic answer to these questions, since this depends on the *motivation* for linking to other communities. For instance, for the validation/verification community, RobMoSys would provide an interesting platform to apply their tools and technology. For such cases, bidirectional workshops to establish such collaborations would seems a good approach.

OPC-UA was mentioned throughout the workshop. I would second the importance of closely monitoring the progress of OPC-UA and the relevant companion specifications. Where applicable, RobMoSys should suggest improvements to OPC-UA to improve aspects such as compositionality.

In terms of outside communities, I believe it would be worthwhile to involve specialists from the domain of *functional programming*. Many functional programmers are familiar with the idea of modeling, verification, code generation and composition. Moreover, from my experience, they are generally interested to apply their techniques to real world use-cases.

### 2.1.3 Involvement and take up of industry and step change

- *how can we reach SMEs? What are their needs? How can we enable / support them to participate / to assist to ramp up the ecosystem?*
- *which of the RobMoSys technical user stories are the ones with the biggest wow-effect?*
- *which of these should we thus have addressed within RobMoSys?*
- *which of these are most interesting and most relevant for illustrating the step change?*
- *which aspects of the pilots are most suited to establish a link to industry?*
- *what metrics would you suggest to measure the success of the RobMoSys approach?*

SME are interested in tools that help them to (immediately) increase quality and/or reduce costs. The user story with the highest potential in that respect is *composition of components*. This is, because this use-case is generally least supported by conventional tooling, but conversely, the complexity involved is significantly higher than for instance is the case with the *component building* use-case. It is worth pointing out that even only with a basic feature set implemented[4] such a toolchain would have a huge benefit. In addition to focusing on this use-case, the suggestions from sections 1.1.1, 1.1.2 and 1.1.4 are most relevant.

To measure the success of the RobMoSys project, I would suggest the following metrics:

[4] e.g. with structural validation, but without timing analysis

- number of contributed models and components available to RobMoSys users
- numbers of active users on the communication platform
- number of paying members at the end of the project

### 2.1.4 Digital data sheet

- *how to describe building blocks with a digital data sheet such that you know what you get and how to use it?*
- *how to generate trust into descriptions, e.g. via testing, simulation, ...*
- *how to ramp up activities for a digital data sheet?*

In the minimal case, a digital data sheet could be nothing more than a human friendly rendering of the information contained in a concrete model. Having this available (and easy to find) would already be useful for existing users and at the same time help to attract new ones. To generate trust, additional tags could be displayed to indicate the QA status of the model. "Only" fulfilling the state of the art and, for instance, "just" providing unit or module testing results would already convey professionalism and thereby instill trust. Additional extended model checking can be added as these become available. To ramp up, as previously suggested, a web-platform `http://models.robmosys.eu` is proposed. This would also allow to introduce user rating features (akin to github stars) as a fuzzy way judge the number of content users of a particular model.

### 2.1.5 Additional Questions

- *Which channels do you recommend for dissemination?*
- *Which strategy do you recommend to get more community involvement?*

The channels which are used today (e.g. conference workshops, community days and the website) are already sufficient to reach a substantial portion of the robotics community. The most valuable (yet uncontrollable) channel for disseminating the RobMoSys approach will be word of mouth propagation of satisfied and excited users that are part of an emerging community! Hence, the best strategy for getting community involvement is to convince users of the added value by means of working tools and to continuously solicit (and incorporate!) their feedback.

# 3 Summary and Conclusions

This section summarizes the main recommendations. Firstly, the main focus should be to focus on **promoting the RobMoSys toolchains and models to *developer roles*** in order to win early adopters. To that end these tools should be visible more prominently on the RobMoSys website, together with a *getting started* tutorial suitable of convincing the passing visitor to try out the tools and to spend more time using them. Secondly, a **searchable model repository** (`http://models.robmosys.eu` with an initial set of models (i.e. their digital data-sheets) will illustrate the potential for model and component reuse and highlight (via the digital-data sheet) the quality standards RobMoSys is bringing forward.

Thirdly, I would recommend **proactively addressing the risks** mentioned, most importantly that of the (perceived) toolchain lock-in.

Lastly, it seems vital to **focus on specific sub-domains and use-cases** as discussed in the workshop and to aim for quality instead of quantity.

# References

[1] *The Yocto Project*. web. URL: `https://www.yoctoproject.org/`.