



## An iterative approach for model-based requirements engineering in large collaborative projects: A detailed experience report

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## Context

- European research projects (ECSEL, Horizon Europe, Celtic, ITEA) with many partners
  - 30-40 on average in some projects
- Diversity of partners (-> good for complementarity):
  - Background
  - Size
  - Application domain
- Interest (technology developer, technology adopter, research)
- Technical level
- Academic vs industrial
- Challenges:
  - Elicitation of needs for technology adopters in different domains
  - Identification of technical solutions per partner
  - Development and evaluation roadmap planning

# Example, Collaboration, Complementarities and Differences (MegaM@Rt project)

		Case study providers									Technology providers (Tools and Methods)																		
		TRT	CSY	IKER	TEK	NOK	VCE	BT	CAM	AINA	SOFT	SMA	ARM	UPAU	ATOS	UCAN	UOC	FTS	UAQ	INT	RO	ABO	SSF	VTT	CON	MDH	SICS	BUT	
Application Domain	Transportation	x	x				x	x	x		Modelio suite	Smartesting Tools (Certifylt / MBeetle)	AM3, EMFViews, Neo4EMF, ATL	Model execution (PauWare, SCXML)	EMF, ATL, Acceleo, OCL, UML2, Profiles		EMFtoCSP, Collaboro		EMF, MOSES, ATL, Acceleo, MARTE, UML2	CHESS (Modeling) & MOSES (Performance Analysis)	Completeness/Consistency Requirements check		LIME toolset		rmig De				
	Smart warehouse			x																									
	Telecom				x	x				x																			
	Industrial Control			x						x																			
Innovation topics	Domain specific languages	x	x			x			x		x	x	x	x	x	x	x					x							x
	Requirements modeling	x			x	x	x	x			x					x				x	x					x			
	Aspect oriented modeling	x									x				x								x						x
	MB Verification	x	x			x	x	x		x					x	x	x	x		x	x	x				x	x	x	
	MB Performance Analysis				x					x						x			x	x									
	Simulation	x		x	x	x		x						x		x											x		
	MB Validation	x	x			x	x	x		x		x			x		x	x	x				x			x	x	x	
	(MB) Runtime verification	x		x	x	x	x	x	x	x				x									x	x	x		x	x	x
	MB testing (online & offline)			x	x	x	x	x	x	x		x				x							x	x		x	x	x	x
	Requirements/system traceability			x		x	x	x			x		x			x					x		x			x	x		
	MB collaboration and governance						x	x			x		x				x	x											
	Continuous Development			x	x	x				x	x	x	x	x	x	x			x				x	x	x				x
	Anti-pattern detection	x													x			x		x									
	Root-cause analysis					x	x	x		x														x	x		x	x	
Model Management & Storage					x					x		x						x	x										

# Model structure (MegaM@Rt project)

- MegaMaRt2Architecture
  - Requirements Level
    - Case Study Scenarios
    - Case Study Requirements
    - MegaM@Rt Tool Set Requirements
      - MMRT Framework Requirements
      - Tool component purpose
  - Architecture Level
    - MegaM@Rt2 Architecture
      - Conceptual Tool Set
        - MegaM@Rt Framework
      - Tool Set Components
        - Common Interfaces
        - Common Frameworks
        - Tool Components

Textual Requirements

Notional Architecture

# Framework requirements (MegaM@Rt project)

The screenshot displays the MegaMaRt2Architecture - Modelio 3.6 application window. The interface includes a menu bar (File, Edit, Configuration, Views, Help), a toolbar with various icons, and a main workspace. On the left, a tree view shows the project structure under 'MegaMaRt2Architecture', including 'RequirementsPurpose', 'MegaM@Rt Tool Set Requirements', and 'Architecture Level'. The main workspace shows a table of system requirements for 'SYS-CSR' under 'System Engineering'.

	Id	Definition	Criticality	Release	References
5	SYS-000001	The SE must support a teamwork collaboration environment.	High	Final	
6	SYS-000002	The SE must provide an advanced graphical user interface (GUI) to simplify the	High	Final	
7	SYS-000004	The SE must support the HW/SW co-design.	High	Final	
8	SYS-000005	The SE must provide smarter design exploration techniques based on a pre-analysis	High	Final	
9	SYS-010100	The SE must support standard modelling languages, standard profiles (i.e. AADL, UML, SysML, MARTE, fUML, UTP) and profile customisation capability.	High	Baseline	
10	SYS-010200	The SE must support domain specific modelling languages (i.e. EAST-ADL, FDB).	High	Baseline	
11	SYS-010400	The SE must provide the mean to generate project and design documents from the	High	Baseline	
12	SYS-020201	The SE must allow modelling the functional requirements based on stakeholder	High	Final	
13	SYS-020202	The SE must allow modelling the non-functional/extra-functional requirements	High	Final	
14	SYS-020300	The SE must extend the "intra-model" requirements traceability across the whole	High	Baseline	
15	SYS-030101	The SE must support the architectural views definition and modelling.	High	Final	
16	SYS-030301	The SE must provide modelling adopting separation of concerns principle.	High	Baseline	
17	SYS-030401	The SE must support the system variability modelling	High	Baseline	
18	SYS-030402	The SE must support the reuse of existing models or patterns	High	Baseline	
19	SYS-040201	The SE must provide the means to model non-functional/extra-functional	High	Baseline	
20	SYS-060000	The SE must provide advanced test design capabilities to support the verification	High	Baseline	
21	SYS-060001	The SE must support the "model in the loop" validation strategy.	High	Baseline	



# Tool components requirements and traceability

	Id	Definition	Criticality	Release	Status
0	MATERA2-010	MATERA2 shall provide UML based modeling and executable specifications.	High	Final	done
1	MATERA2-020	MATERA2 shall provide UML based simulation facilities.	High	Final	done
2	MATERA2-030	MATERA2 shall generate a human-friendly report in order to visualize the test and	High	Final	done
3	MATERA2-040	MATERA2 shall provide feedback to the modeling phase, including timing	High	Final	done

Diagram showing traceability relationships:

- MATERA2 (ABO) satisfies MATERA2-010.
- MATERA2-010 traces to SYS-010100.
- SYS-010100 traces to IKER\_01, NOK\_01, and TEK\_02.

Tool component

Tool Requirement

Framework Requirement

Case Study Requirements

# Roadmap example (MegaM@Rt project)



time

Framework Features	Baseline	Initial	Intermediate	Final
	110			
<b>RTA-00006:</b> The framework shall provide requirement traceability facilities at runtime	CERTIFYIT-110 CQDESIGN-060	JTL-050 [done]	JTL-030 [in progress] JTL-040 [in progress] MBEETLE-090 MBEETLE-110	MATERA2-090 MBEETLE-100
<b>RTA-00007:</b> Trace monitoring and online testing at runtime shall improve trace analysis results and localization of faults	AIPHS-010 AIPHS-020 AIPHS-030 CERTIFYIT-080 CERTIFYIT-090		MBEETLE-090	AIPHS-060 [planned] COMPTTEST-030
<b>RTA-00008:</b> Trace monitoring and online testing shall be combined at runtime to verify functional as well as non-functional properties in a synergic way	MATERA2-070 AIPHS-010 AIPHS-020 AIPHS-030	LIME-010 [done]		MBEETLE-010 [in progress] COMPTTEST-030
<b>RTA-00009:</b> Trace analysis tools shall be able to collect and analyse information from different sources and using different techniques				JTL-060 PADRE-060 [planned]

Framework Requirements

Tool Requirement

# Generated documents (MegaM@Rt project)

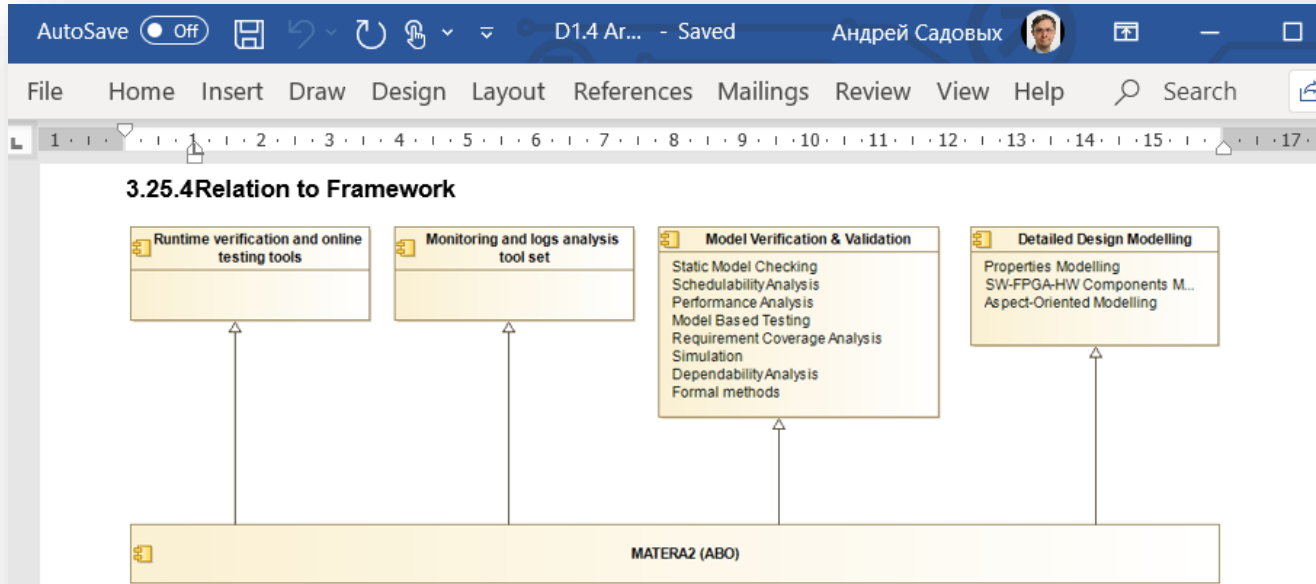


Figure 107 Relation to Framework

## Details on realized conceptual tools

Relation	Conceptual Tool	Category
The model can be simulated and verified using UPPAAL with respect to the requirements of the system.	Runtime verification and online testing tools	Runtime Analysis Tool Set
MBM <sup>AA</sup> provides monitoring support and allows to analyze execution traces specified in textual format.	Monitoring and logs analysis tool set	Runtime Analysis Tool Set
The MATERA2 tool set allows to model functional and non-functional properties of real-time systems which can be simulated and verified using UPPAAL.	Model Verification & Validation	System Engineering Tool Set
Functional and non-functional properties of real-time systems are modeled with UPPAAL timed automata.	Detailed Design Modelling	System Engineering Tool Set

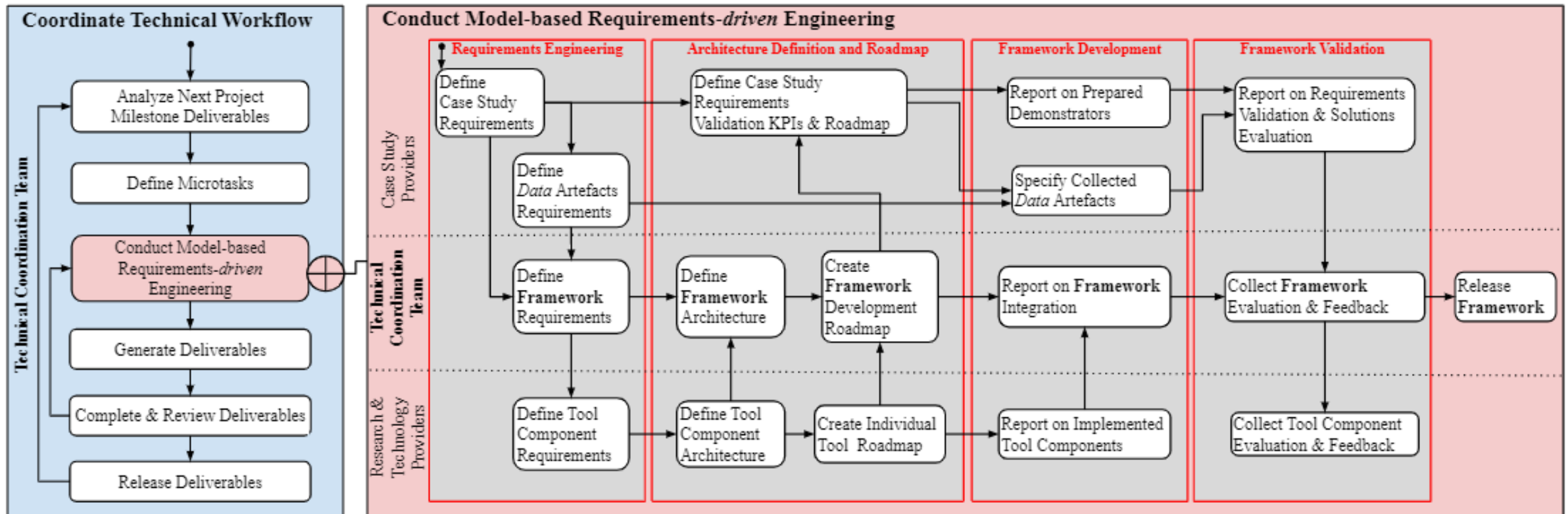
Table 158 Relations

- Live document
- Unified project document style
- In sync with Requirements and Architecture changes
- Submitted as a project deliverables with minor polishing

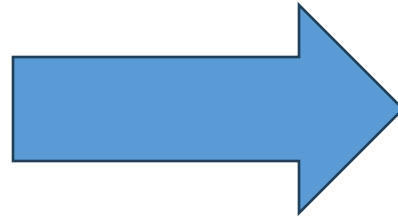
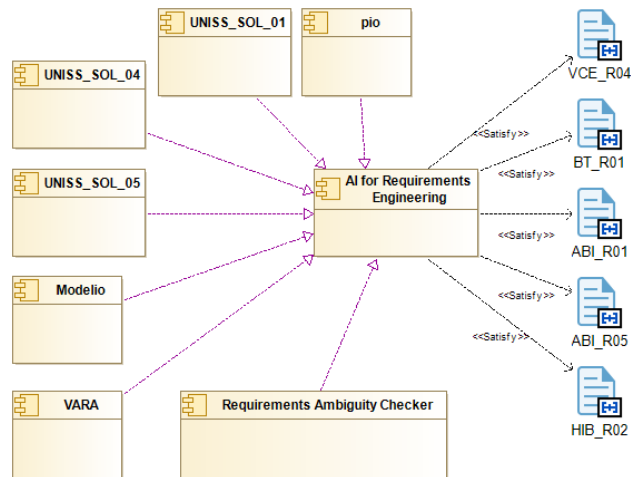
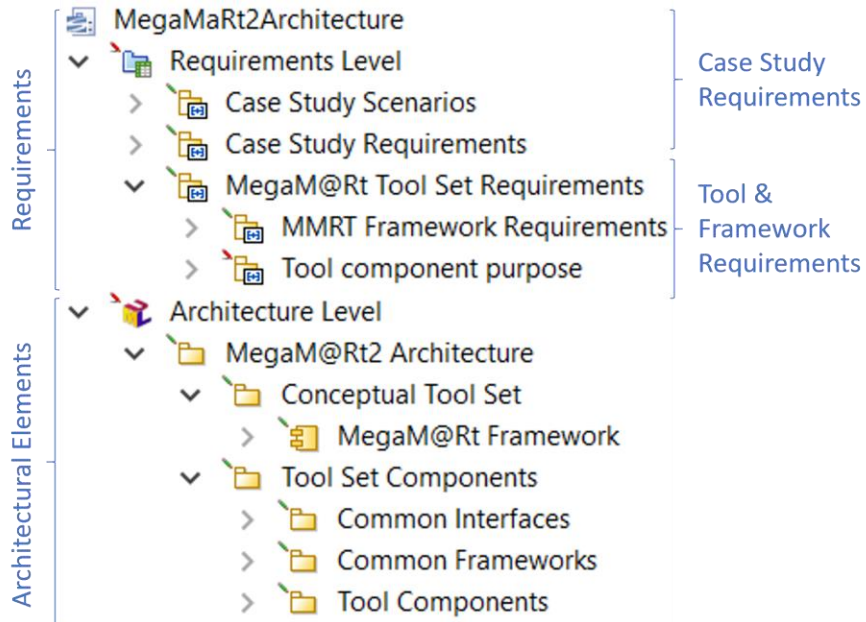


# An Iterative Approach for Model-based Requirements Engineering in Large Collaborative Projects: A Detailed Experience Report

7 years, 5 collaborative projects, 100s engineers, MBRE



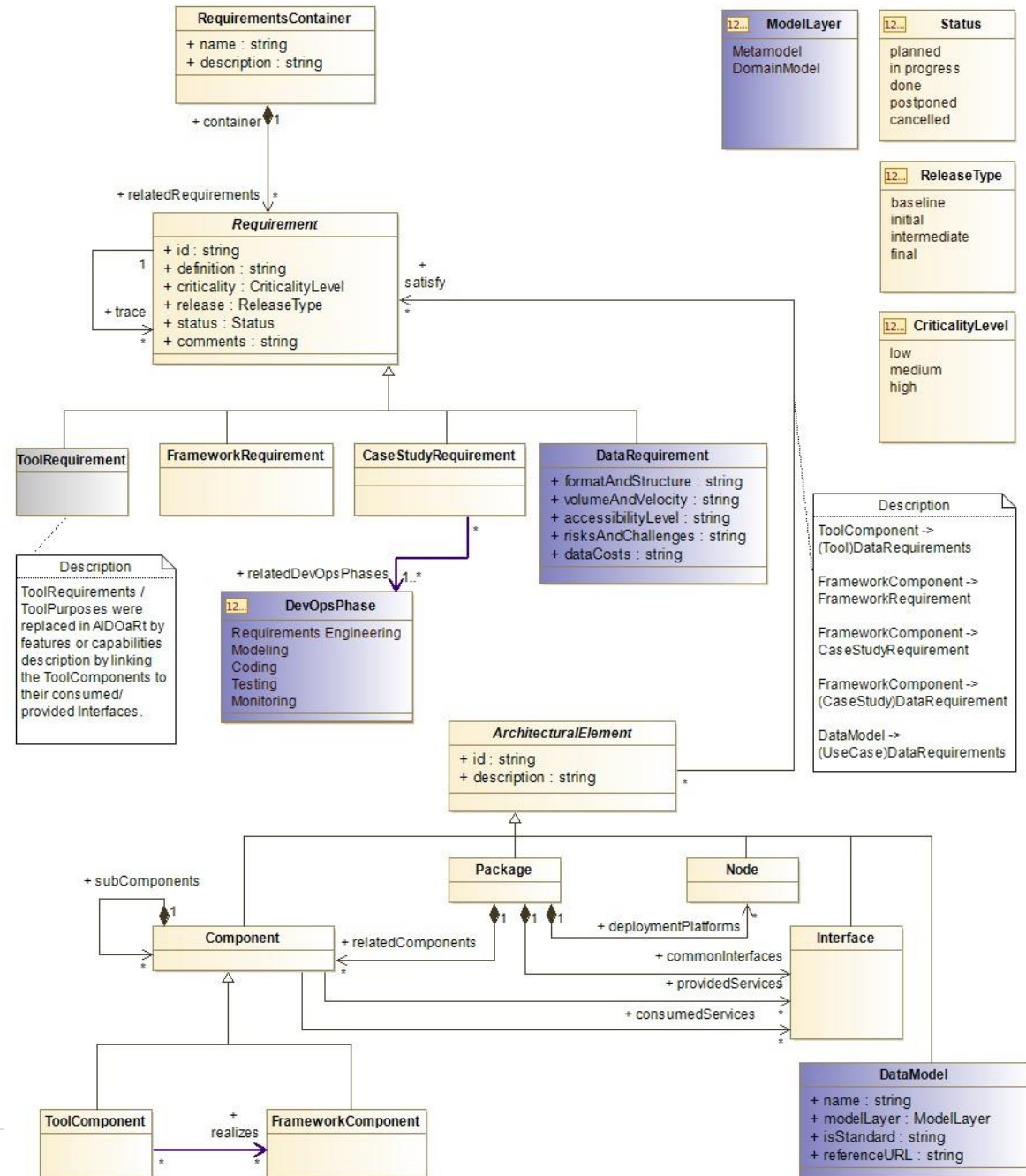
# Tool support: modelling, analysis, documents



The grid contains 12 thumbnails of documents:

- 1. AIDO@RT Cover Page: AI-Augmented automation supporting modelling, coding, testing, monitoring and continuous development in Cyber Physical Systems.
- 2. Document Revision Log: A table with columns for ID, Date, Author, and Description.
- 3. Executive Summary: Overview of the AIDO@RT project and its goals.
- 4. Table of Contents: A list of sections and their page numbers.
- 5. Table of Contents for AI@Rt Framework: A list of sections and their page numbers.
- 6. Table of Contents for AI@Rt Framework: A list of sections and their page numbers.
- 7. Table of Contents for AI@Rt Framework: A list of sections and their page numbers.
- 8. Test Code Generator: A diagram showing the flow from requirements to test code.

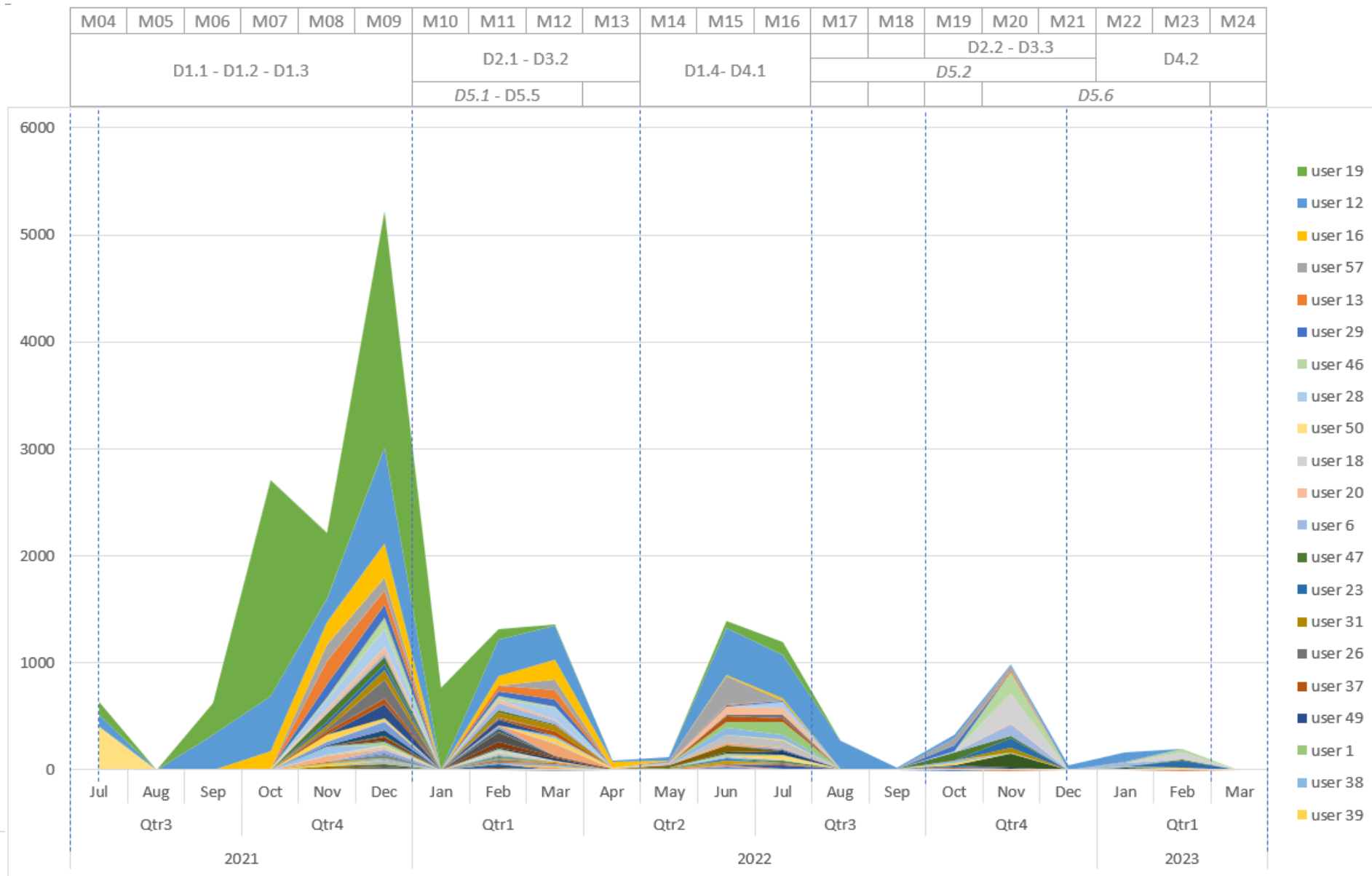
# Extended Metamodel (AIDOaRt)



## Modelling scale

Number of	DataBio	REVaMP2	MegaM@Rt2	VeriDevOps*	AIDOaRt*
Partners	48	27	27	7	31
Countries	17	5	6	4	7
Case studies	27	7	9	2	15
Project months	36	36	36	36	36
Registered users	55	43	56	15	100
Contributors	31 (56%)	24 (56%)	27 (48 %)	7 (47%)	60 (60%)
Commits	958	534	1322	328	2548
Requirements: (Case Study r. + Framework r. + Tool r.)	=181 77 104 NA <sup>#</sup>	=535 190 56 289	=428 106 91 231	=124 39 NA <sup>\$</sup> 85	=455 363 17 75
Model elements <sup>†</sup> (Requirements + Architecture)	=5406 535 4871	=3307 1091 2216	=4744 2351 2393	=2087 1211 876	=9512 3507 6005
Pages generated	61	109	125	120	~160 x 11 <sup>‡</sup>

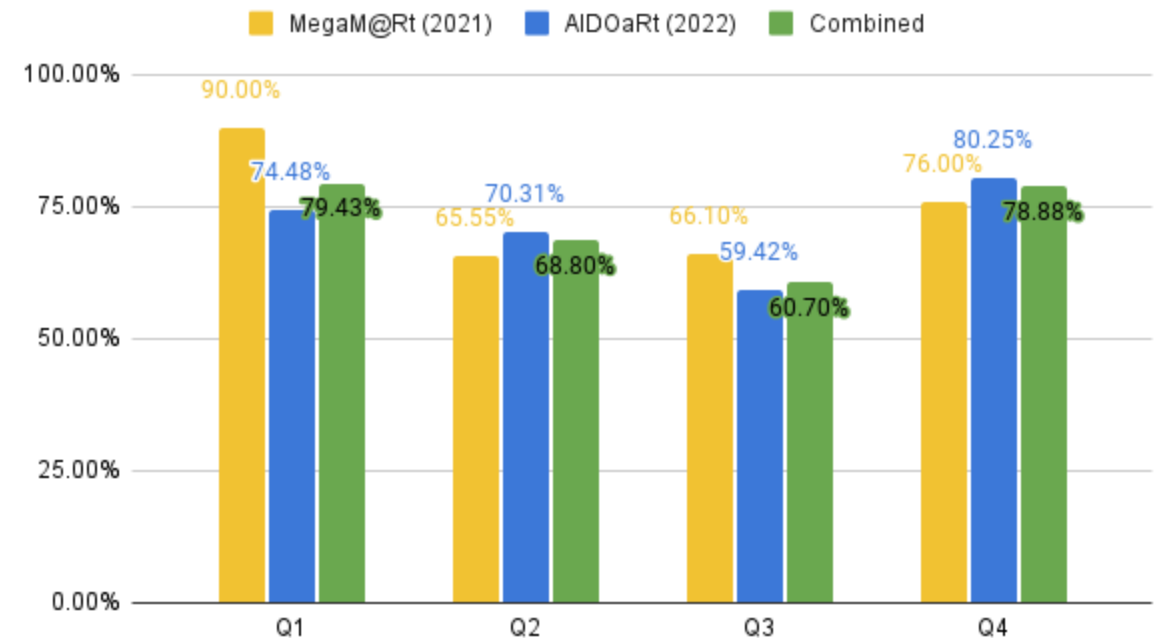
# Modelling intensity over the time



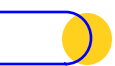


## 46 project participants. Overall positive feedback

- Q1: In your opinion, did you find this graphical model-based approach useful in different activities of Requirements Engineering?
- Q2: In your opinion, do you see the modeling approach as an improvement compared to other non-modeling (e.g., text-only or table-based) regarding the following aspects?
- Q3: In your opinion, did you find the following Modelio tool features useful in different Requirements Engineering activities?
- Q4: Please indicate your opinion on the implementation of the MBRE approach using Modelio.







# Overall assessment

## Lessons

- Model as a common language
- Project Planning
- Framework Architecture
- Language and Model Complexity
- Learning Curve
- MBRE and Collaboration

## Challenges

- From Requirements to Source Code
- User Training and Support
- Collaborative and Online Model Editing
- Automation and Production-Readiness

## Demonstrated

- Scalability
- Heterogeneity
- Adaptability and Extensibility
- Traceability
- Automation
- Consistency and Quality
- Usefulness and Usability

● Thank you for your attention

Questions?



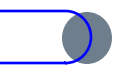
**VeriDevOps Research Workshop**

CyberSecurity in a DevOps Environment

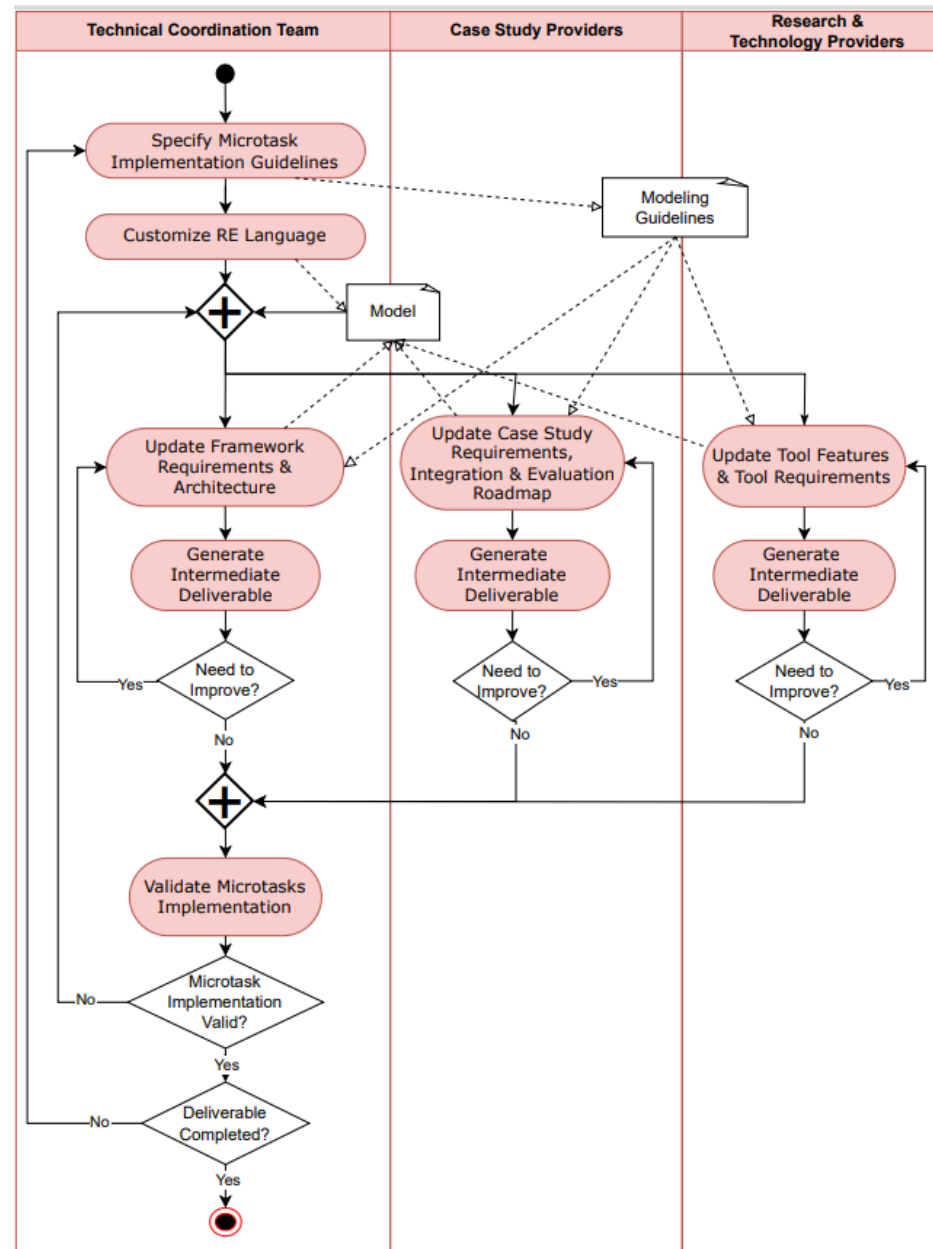
Join the workshop to know the newly Launched book!

Time: 9:30-13:30 (CET)

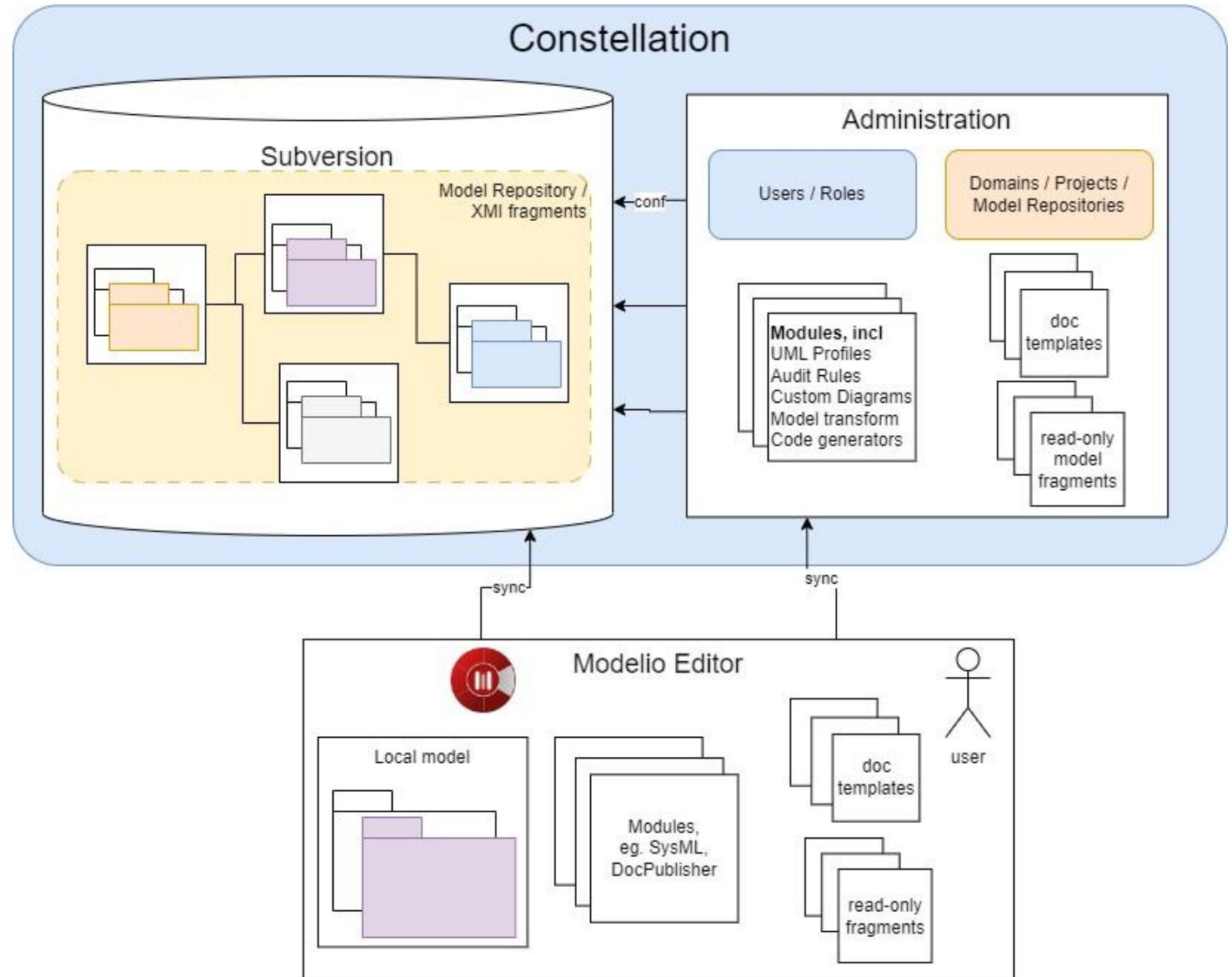
**26TH**  
October 2023



# Micro-tasks



# Implementation



# VeriDevOps - automating security requirements verification in DevOps

