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ACROBA
connect & produce through agile production

D9.17 Final Progress Report

WP9

BFH

Delivery Date 2024.12.31

Dissemination Level: CO

Version V1

Berner Fachhochschule

The ACROBA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017284.

Approval Status

	Name and Surname	Role in the Project	Partner(s)
Author(s)	Management Team	Management Team	BFH
Reviewed by	WP leaders and Risk Manager	WP leaders and Risk Manager	DEUSTO, SIGMA, IMR, STER, NUTAI, EMC2, ROB, AITIIP
Approved by	Norman U. Baier	Project Coordinator	BFH

History of Changes

Version	Date	Description of Changes	By
0.1	2024.11.20	First Draft	Management Team
0.2	2024.12.18	Revised Draft	Management Team
1	2024.12.20	Final Version	Management Team

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Disclaimer:

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Executive Summary

The present document gives an overview of the work carried out during the period from M1 (January 2021) to M48 (December 2024), which is the entire timeline of the project. First, the specific objectives and sub-objectives are reviewed and the progress towards their achievement is stated. Then, an overview of the project timeline, milestones and deliverables is given, and the results of the work that has been carried out in the specific work packages in the last months is covered. In the final section, an overview of the financial management and the results is described.

1 Objectives

This section presents the specific objectives for the ACROBA project and describes the work carried out towards the achievement of each objective.

1.1 Strategic Objective 1

Design a novel platform for enabling fast and cost-efficient deployment at scale of robot systems, end efforts and sensors deployment, adaptation, and operation of self-adaptive solutions within agile production industrial scenarios.

Sub-objectives	Progress	Work done in
1.1 Design of the ACROBA robotic modular platform based on the reference architecture COPRA-AP, scalable and configurable to the target industrial needs	100%	WP1
1.2 Develop mechanisms for the adaptation and integration of the ACROBA platform to the robot solutions of the industrial manufacturing through reconfigurable sensorized robotic cell and Integration of model based digital twin architecture, fast programming modules by human operators using sensorized dummy tools.	100%	WP3

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1.3 Establish a multi-modal perception guided robot control model for precise visual-contact product features and safe human interaction	100%	WP2

1.2 Strategic Objective 2

Advanced training and transfer learning agile mechanisms to provide autonomous robot solutions with enhanced cognitive capabilities.

Sub-objectives	Progress	Work done in
2.1 Dynamic robot programming techniques (Cognitive task planner models) to automatically generate the robot tasks from CAD files and human demonstrations with dummy tools.	100%	WP2
2.2 Decision making module based on Deep Reinforced Learning (DRL) for distributed coordination of autonomous and collaborative robots at scale (e.g., adapting autonomous robot task planning and human robot collaboration actions or task planning under production incidents.	100%	WP2
2.3 Generation of a Virtual Gym environment (set on digital twins) for agile production scenarios for obtaining the required optimal behaviour in robots	100%	WP2

1.3 Strategic Objective 3

Validate ACROBA platform in large scale agile production scenarios.

Sub-objectives	Progress	Work done in

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3.1 ACROBA platform will be demonstrated and validated in five industrial Pilot Lines. These Pilot lines will be the following: Plastic product manufacturing industry at CABKA (DE) and MOSES (ES); Medical devices manufacturing at STER (IE), Electric motors components at ICPE (RO) and electronic devices at IKOR (ES).	100%	WP4, WP5 & WP6

1.4 Strategic Objective 4

Ecosystem roll out: knowledge transfer and reach out to agile production industry stakeholders.

Sub-objectives	Progress	Work done in
4.1 Replicate the ACROBA platform to other scenarios via the organization of Hackathons and ACROBA On-Site Labs (AOSLs) for manufacturing SMEs.	100%	WP6 & WP7
4.2 Create a community of practice by providing access to ACROBA research data to developers of AI and robotics applications via the different dissemination channels.	100%	WP7
4.3 Setting up liaison and co-operation activities with DIH network.	100%	WP7
4.4 Ecosystem set up for the future Platform roll out and exploitation	100%	WP6 & WP8

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2 Project Overview

The ACROBA project started in January 2021 and ends in December 2024 (duration of 48 months). In the last 24 months, the consortium has achieved the remaining results to reach the final goals of ACROBA. Figure 1 presents the GANTT chart for the ACROBA project, which circles the period that is being reported in orange.

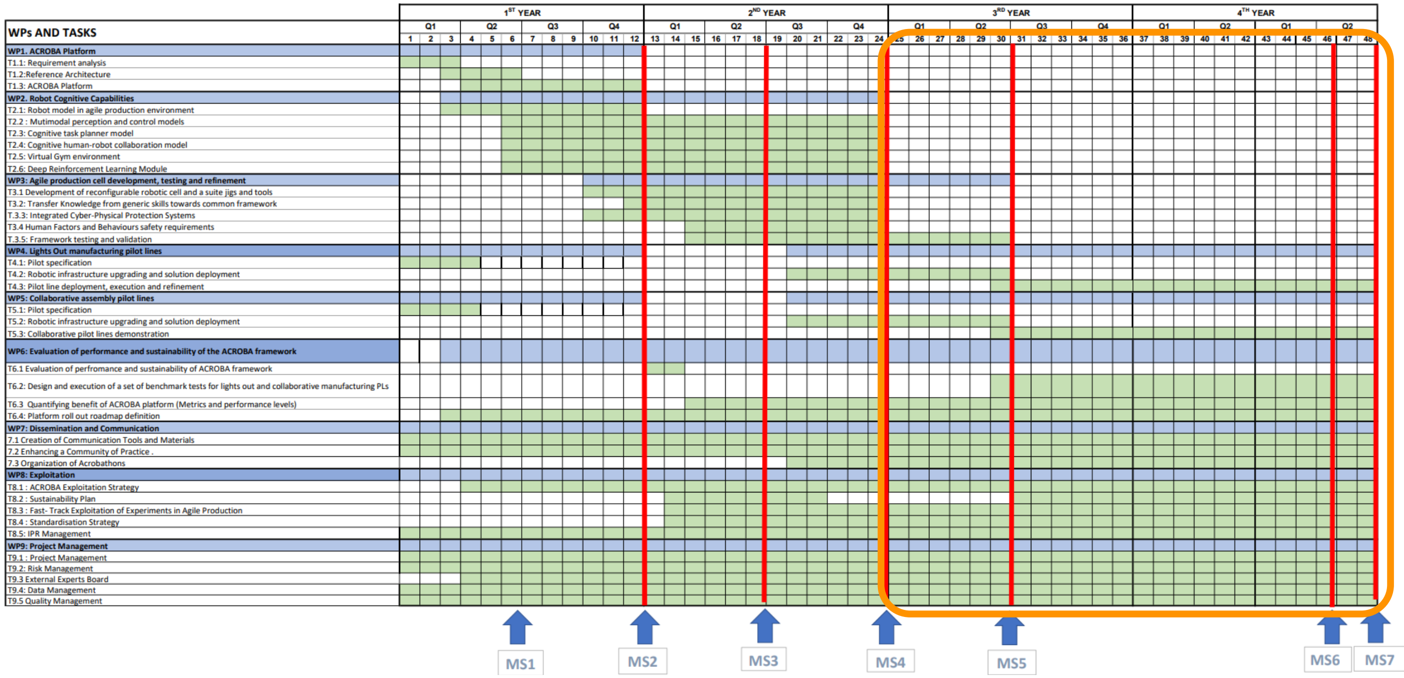

Figure 1 GANTT chart

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It is noticeable from the GANTT chart that the ACROBA project has reached the last three milestones MS5 Integration of ACROBA Platform in the pilots' lines, MS6 Hackathons and MS7 Validation of ACROBA Platform and successful conclusion of the project.

Table 1 reports the list of milestones updated with an explanation of the status at the moment of writing this deliverable.

Table 1 List of milestones

Ref	Milestone	Leader	Means of verification	Due Date	Status	Comments
MS1	Reference Architecture Outlined	BFH	In this milestone the architecture of ACROBA is outlined	M6	Achieved	The outline of the architecture outlined in D1.2
MS2	1) ACROBA platform architecture defined, and 2) Pilot lines prepared for implementation	BFH	ACROBA platform architecture defined, and pilot lines prepared for implementation	M12	Achieved	The ACROBA platform architecture is defined and implementation for pilot lines has started.
MS3	Robotic cell	IMR	Prototype available and working at IMR facilities	M18	Achieved	The robotic cell is defined and specified.
MS4	Robot Cognitive Capabilities	SIGMA	Robot Cognitive Capabilities	M24	Achieved	The Capabilities are defined and implemented.
MS5	Integration of ACROBA Platform in the pilots' lines	NUTAI	Validation report showing the commissioning phase successfully completed	M48	100%	All software and hardware fully installed and operative.

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MS6	Hackathons	EMC2	Report of the hackathon and videos released showing the events	M48	100%	5 mini hackathons (DEUSTO, BIBA, SIGMA, BFH, IMR) and 1 mega hackathon (ROB, VICOM, BIBA, BFH) Alternative events organized: Automatica 2023, ERF 2024, ROSConFr 2024
MS7	Validation of ACROBA Platform and successful conclusion of the project	BFH	Validation of ACROBA Platform and successful conclusion of the Project	M48	100%	The ACROBA platform is validated with 5 use cases scenarios and two external companies (ENSTO and Croom Medical). Performances were evaluated and reported. The ACROBA project is closed successfully.

Similarly, Table 2 reports the list of deliverables and their status at the moment of writing this deliverable.

Table 2 List of deliverables

Del. Nº	WP	Deliverable name	Leader	Type	Date	Status	Comments
D1.1	1	Requirements' traceability matrix	DEU	Report	M3	Approved	Delivered on time
D7.1	7	First batch of communication materials	EMC2	Website, templates, fillings, etc.	M3	Approved	Delivered on time
D7.2	7	Initial Dissemination & Communication Plan	EMC2	Report	M3	Approved	Delivered on time
D9.1	9	Project Hand Book	BFH	Report	M3	Approved	Delivered on time. A new version was updated in January 2022 (as suggested by the Project Officer) due to some

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							changes performed in the handbook (living document) during June-July 2021.
D9.2	9	Data Management Plan	BFH	ORDP	M3	Approved	Delivered on time
D9.7	9	Risk Breakdown structure (RBS) V1	AITIIP	Report	M3	Approved	Delivered on time
D4.1	4	Medical device pilot line specifications	STER	Report	M4	Approved	Delivered on time
D4.2	4	Plastic pilot line specifications	MOS	Report	M4	Approved	Delivered on time
D5.1	5	Electronic components pilot line specifications	IKOR	Report	M4	Approved	Delivered on time
D5.2	5	Electric motor pilot line specifications	ICPE	Report	M4	Approved	Delivered on time
D1.2	1	Reference architecture	DEU	Report	M6	Approved	Delivered on time
D2.1	2	Robot Modules Architecture (Preliminary version)	DEU	Report	M6	Approved	Delivered on time
D7.3	7	Second batch of communication materials	EMC2	Video, prints, designs, etc.	M6	Approved	Delivered on time
D7.4	7	Stakeholders database	IMR	Report	M6	Approved	Delivered on time
D8.2	8	Communication and Dissemination Master Plan (CDMP)	ROB	ORDP	M6	Approved	Delivered on time
D9.12	9	Data Management Plan	BFH	ORDP	M6	Approved	Delivered on time
D9.16	9	Quality assurance plan	BFH	Report	M6	Approved	Delivered on time
D10.1	10	POPD- Requirement No.1	BFH	Ethics	M6	Approved	Delivered on time
D9.8	9	Risk Breakdown structure (RBS)v2	AITIIP	Report	M9	Approved	Delivered on time

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D4.6	4	Technology Feasibility Studies. Initial report	STER	Report	M10	Approved	Delivered by email to the Project Officer (the EU portal did not allow to upload the document). On time
D5.7	5	Technology Feasibility Studies. Initial report	VICOM	Report	M10	Approved	Delivered by email to the Project Officer (the EU portal did not allow to upload the document). On time
D1.3	1	ACROBA Platform	DEU	Other	M12	Approved	Delivered on time
D2.2	2	Robot Modules Architecture (final version publishable)	DEU	Report	M12	Approved	Delivered on time
D9.3	9	Project Management Report (v1)	BFH	Report	M12	Approved	Delivered on time
D6.1	6	Test Scenarios definition and Scenario's baseline	BFH	Report	M14	Approved	Delivered on time
D2.3	2	Cognitive API (cAPI) of the Perception-Control Models (preliminary version)	SIG	Other	M15	Approved	Delivered on time
D2.7	2	Virtual Gym prototype (preliminary version)	VIC	Demonstration	M15	Approved	Delivered on time
D4.7	4	Technology Feasibility Studies. Conclusions	STER	Report	M16	Approved	Delivered on time
D5.8	5	Technology Feasibility Studies. Conclusions	VICOM	Report	M16	Approved	Delivered on time
D3.1	3	Definition of the Robotic cell (preliminary version)	IMR	Report	M18	Approved	Delivered on time
D7.5	7	Dissemination and Communication Plan update	EMC2	Report	M18	Approved	Delivered on time

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D8.1	8	Exploitation Strategy	ROB	Report	M18	Approved	Delivered on time. Rejected and resubmitted on 17/05/2023.
D8.11	8	IPR Report	BFH	Report	M18	Approved	Delivered on time
D9.9	9	Risk Breakdown Structure (RBS) v3	AITIIP	Report	M18	Approved	Delivered on time
D9.13	9	Data Management Plan v2	BFH	Report	M18	Approved	Delivered on time
D8.5	8	Sustainability Plan	ROB	Report	M21	Submitted	Delivered on time. Rejected and resubmitted on 17/05/2023.
D8.7	8	Exploitable results in Agile Production	ROB	Report	M21	Approved	Delivered on time
D8.9	8	Standardization Strategy	BIBA	Report	M21	Submitted	Delivered on time. Rejected and resubmitted on 31/07/2023
D9.4	9	Project Management Report v2	BFH	Report	M21	Approved	Delivered on time
D2.4	2	Cognitive API (cAPI) of the Perception-Control Models (final version)	SIG	Other	M24	Approved	Delivered on time
D2.5	2	Toolkit for human-robot collaboration	SIG	Report	M24	Submitted	Delivered on time. Rejected and resubmitted on 02/10/2024
D2.6	2	Dynamic Programming of robots	AITIIP	Other	M24	Approved	Delivered on time
D2.8	2	Virtual Gym prototype (final version)	VIC	Demonstration	M24	Approved	Delivered on time
D2.9	2	Deep Reinforcement Learning module implementation	DEU	Other	M24	Approved	Delivered on time
D3.2	3	Definition of the Robotic cell (final version)	IMR	Report	M24	Approved	Delivered on time

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D3.5	3	Safe integration of collaborative robots	BIBA	Report	M24	Submitted	Delivered on time. Rejected and resubmitted
D3.6	3	Cognitive API of the Perception and Control	SIG	Other	M24	Approved	Delivered on time
D3.3	3	Demonstration of fully automate skills	IMR	Demonstration	M30	Submitted	Delayed. Submitted on 03/07/2023.
D3.4	3	Demonstration of collaborative assembly skills	IMR	Demonstration	M30	Submitted	Delayed. Submitted on 05/07/2023.
D4.4	4	Report on integration of the ACROBA platform to specific use case	AITIIP	Report	M30	Submitted	Delivered on time
D5.3	5	Report on integration and customization of generic ACROBA solution	NUTAI	Report	M30	Submitted	Delivered on time
D6.7	6	Validation Report V1	BFH	Report	M30	Submitted	Delayed. Submitted on 05/07/2023.
D9.5	9	Project Management Report v3	BFH	Report	M30	Submitted	Delivered on time.
D8.3	8	Exploitation Strategy v2	ROB	Report	M36	Submitted	Delayed. Submitted on 30/10/2024.
D8.12	8	IPR Report v2	BFH	Report	M36	Submitted	Delayed. Submitted on 11/10/2024.
D9.10	9	Risk Breakdown Structure (RBS) v4	AITIIP	Report	M36	Submitted	Delivered on time.
D9.14	9	Data Management Plan v3	BFH	Report	M36	Submitted	Delivered on time.
D8.8	8	Fast-track Exploitation of Experiments in Agile Production	IMR	Report	M45	Submitted	Delivered on time.

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D4.5	4	Final demonstration of ACROBA platform executing use case	STR	Report	M46	Submitted	Delayed. Submitted on 4/12/2024
D5.5	5	Collaborative assembly use cases	NUTAI	Report	M46	Submitted	Delivered on time.
D5.6	5	Final demonstration of ACROBA platform executing use case	NUTAI	Report	M46	Submitted	Delivered on time.
D6.3	6	Final demonstration tests in plastic device setting	MOS	Other	M46	Submitted	Delivered on time.
D6.4	6	Final demonstration tests in medical device setting	STER	Other	M46	Submitted	Delayed. Submitted on 10/12/2024
D6.5	6	Final demonstration tests in Electric motors setting	ICPE	Other	M46	Submitted	Delivered on time.
D6.6	6	Final demonstration in Electronic devices setting	IKOR	Other	M46	Submitted	Delivered on time.
D9.11	9	Risk Breakdown Structure (RBS) v5	AITIIP	Report	M46	Submitted	Delivered on time.
D8.10	8	Standardisation Strategy (final report)	BIBA	Report	M47	Submitted	Delayed. Submitted on 19/12/2024
D9.19	9	Report on cumulative expenditure incurred 2024	BFH	Report	M47	Submitted	Delivered on time.
D7.6	7	Masterthon	EMC2	Website, patents, fillings, etc.	M48	In progress	It will be submitted on time 31/12/2024
D4.3	4	Lights out Pilot line use cases description	IMR	Report	M48	In progress	It will be submitted on time 31/12/2024

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D5.4	5	Collaborative Pilot line use case description	NUTAI	Report	M48	In progress	It will be submitted on time 31/12/2024
D6.2	6	ACROBA scenarios benchmarking tests	EMC2	Report	M48	In progress	It will be submitted on time 31/12/2024
D6.8	6	Validation report Final version	BFH	Report	M48	In progress	It will be submitted on time 31/12/2024
D6.9	6	Platform requirements data management and mapping	AITIIP	Report	M48	Submitted	Delivered on time.
D6.10	6	Web Platform Release for implementing the solution	AITIIP	Website	M48	Submitted	Delivered on time.
D6.11	6	General Report on the SEP for the ACROBA Ecosystem	AITIIP	Report	M48	Submitted	Delivered on time.
D7.7	7	Final Dissemination & Communication Plan	EMC2	Report	M48	In progress	It will be submitted on time 31/12/2024
D8.4	8	Exploitation Strategy v3	ROB	Report	M48	In progress	It will be submitted on time 31/12/2024
D8.6	8	Sustainability Plan	ROB	Report	M46	Submitted	Delivered on time.
D8.13	8	IPR Report (final version)	BFH	Report	M48	In progress	It will be submitted on time 31/12/2024
D9.6	9	Project Management Report v4	BFH	Report	M48	Submitted	Delivered on time.
D9.15	9	Data Management Plan v4	BFH	Report	M48	Submitted	Delivered on time.
D9.17	9	Final Progress Report	BFH	Report	M48	Submitted	Delivered on time.

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2.1 Risk Management

Comentado [TW1]: @Jose Antonio

Under the scope of WP9 (Management), the management of the risks related to the project is performed. During the first year of the project, the methodology initially designed for the monitoring of the risks (D9.7, M3) was updated and included in D9.8 (M9) and D9.9 (M18). A detailed relation of all risks identified can be found in that deliverables.

The initial risk management methodology was presented in previous Deliverables (D9.7), while D9.8 presented the improvements in the methodology implemented for the following periods. D9.9 improved the methodology, and introduced contingency plans, as finally the complete running methodology is deployed in this D9.10.

Therefore, the following tables contain a summary of the risks that have been materialized and solved during the period M25-M48. Most of the risks have information on the current situation and avoidance strategy, i.e., how to avoid the risk. In addition, a more detailed description about the mitigation plans for those risk with high level (10 and 25) has been considered. This will allow for a more proactive and predictive management of the project. In the case of materialized risks, a different management is ongoing. In this case a contingency detailed individualized plan is done, in other to have a clear view of the real evolution of these particular risks.

From month 25 to M48 of the project, risk management has been carried out as estimated in the methodology. General periodic meetings for risk management have been held monthly, along with additional meetings with specific partners to address risks that required targeted intervention. Throughout the project, various risks have materialized, and their management has been carried out using the contingency plan templates, establishing specific actions whose execution has effectively mitigated the risks.

The following figure shows the evolution of the accumulation of identified risks at three specific points in the project, corresponding to months M24, M36, and M48.

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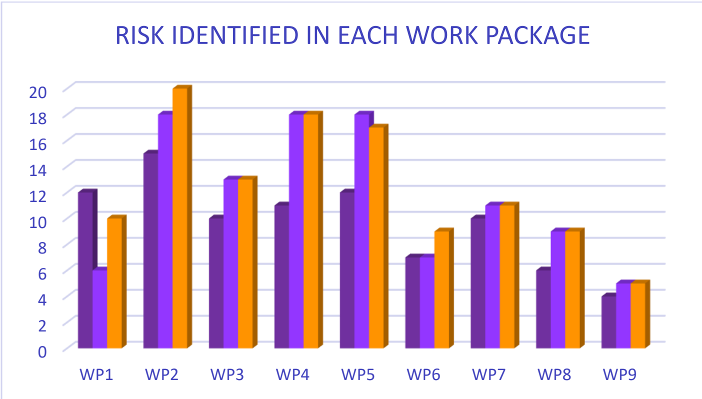

Figure 2 Risks identified per WP, in M24, M36 and M48

The same exercise can be performed by observing the number of risks identified by each partner in M24, M36, and M42. It is worth noting that, as in the previous chart, there is a decrease between M24 and M36 in some cases. This is due to the presence of duplicate risks in M24, which were purged and eliminated in M36.

Figure 3 Risks identified per partner, in M24, M36 and M48

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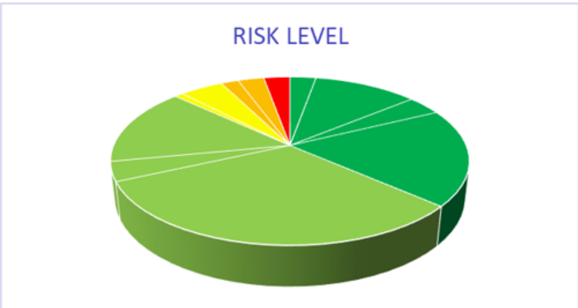
As established in the methodology, each potential risk identified during the project has been categorized based on its impact and probability of occurrence. From this, a risk level category has been assigned. Throughout the project, risks of different levels have been identified, which were grouped by their levels to categorize their management.

The following figure provides the statistics of the potential risks identified throughout the project, along with their categorization based on the level of risk.



RISK LEVEL	PERCENTAJE
1	3%
2	11%
3	3%
4	18%
6	33%
8	3%
9	15%
10	1%
12	5%
15	2%
16	3%
20	3%

Figure 4 Statistics of the potential identified risks depending on the risk level

As previously established, the detection of a risk does not mean it has occurred; it only indicates a potential risk. If the risk materializes, its status changes to "materialized," and its management process differs. This has occurred throughout the project with several risks, which have been managed using the Risk Contingency templates. By M48, all of these risks have been managed, and as a result, they have progressively transitioned to the "solved" status. The following image shows the folder in the shared Teams workspace, listing the documents related to the risks that followed this management process.

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Documentos > General > WP9 - Management > 09_Risk Contingency Plan > **solved**

Nombre	Modificado por	Modificado
RCP_10.docx	José Antonio Dieste	8 de mayo
RCP_101.docx	José Antonio Dieste	8 de mayo
RCP_103.docx	José Antonio Dieste	4 de diciembre
RCP_104.docx	José Antonio Dieste	4 de diciembre
RCP_105.docx	Court Edmondson	10 de diciembre
RCP_27.docx	José Antonio Dieste	25.02.2023
RCP_33.docx	José Antonio Dieste	8 de mayo
RCP_49.docx	Alejandro Muñoz Espi:	14.09.2022
RCP_61.docx	José Antonio Dieste	11.07.2023
RCP_66.docx	José Antonio Dieste	3 de abril
RCP_86.docx	SOULARD Lucie	02.02.2023
RCP_99.docx	José Antonio Dieste	25.02.2023

Figure 5 List of Materialised risk in the project, that were solved

All the detailed information on risk management during this second period can be found in the RiskLog.xls template of the ACROBA management system and is documented in deliverables D9.10 and D9.11.

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3 Explanation of the Work Carried Out by WP

The following sub-sections describe the progress during the period from M24 to M48 in each Work Package.

3.1 Work Package 1

WP number	1	Months	1-12
WP title	ACROBA platform		
Lead Partner	DEUSTO		
Contributing partners	BFH, BIBA, MRNEC, AITIIP, CABKA, IKOR, SIGMA, IMR, NUTAI, STER, STAM, ICPE, VICOM, MOS		

3.1.1 Objectives

The objectives of this work package are:

- to gather and define the industrial and value chain requirements for the design of the Platform,
- to define the robotic reference architecture for the development of the platform (generic and use case specific) based on existing architectures (i.e., COPRA-AP),
- to build the novel ACROBA platform for agile production: programming of the necessary modules for the assembly of this architecture based on COPRA-AP Framework.

3.1.2 Activities

The activities in WP1 have been developed between M1 and M12, and the work has been finished and reported in previous documents (RP1 technical report, D9.4 Project Management Report (V2)). The outcomes are available in D1.1 to D1.3.

Task 1.1 Requirement analysis (M1-M3): finished

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During this phase, a comprehensive analysis of requirements for different use cases was conducted, identifying functional and non-functional needs. This task was closely coordinated with T4.1 and T5.1 to align pilot specifications with the broader requirements. The primary output was a requirements traceability matrix, which connected requirements to validation tests and identified associated risks.

Task 1.2 Reference Architecture (M3–M6): finished

The ACROBA platform's architecture was defined using COPRA-AP as the foundation. It incorporated ROS for factory-level and FIWARE for office-level communication layers. Efforts included mapping use-case-specific requirements to the architecture and addressing both consortium-specific needs and general information in public and private documentation. This ensured the architecture’s adaptability and scalability for diverse industrial scenarios.

Task 1.3 ACROBA Platform (M4-M12): finished

The implementation of the architecture culminated in the creation of a functional first version of the ACROBA platform. This was hosted on a private GitHub repository and was designed with Docker to ensure scalability and ease of deployment. Tools and dependencies were streamlined to facilitate installation and use by project partners.

While maintaining the first overall idea (use of Docker, ROS, package type, etc.) the structure of the platform has evolved from one single Docker to several Docker images/containers.

The evolution was necessary to obtain the following benefits:

- facilitate modules integration
- provide a decoupled development environment (each developer being responsible of its docker image)
- Simplify setup, deployment and version management of the platform and its modules.

After doing this the integration of use case was greatly simplified:

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The ACROBA platform then consisting of a generic part (use case independent), which can be deployed and used swiftly. The platform provides base image templates for the so called "cell config", which integrates a use case dependencies and specificities. They are specifically intended to ease the development process. A use case "cell config" is integrated at runtime.

3.1.3 Partners' roles

In Work Package 1 (WP1), the lead partner was DEUSTO, which managed the work package, led all tasks, and was responsible for creating the deliverables, including implementing the ACROBA architecture in the GitHub repository. DEUSTO coordinated the efforts of all contributing partners.

BFH played a key role in meetings and discussions, provided support for testing and troubleshooting issues as part of WP6 and WP9 roles, and contributed to the specification of the Task Planner section of the architecture. BIBA worked on information gathering and requirement engineering, with a particular focus on Human-Robot Collaboration (HRC). MRNEC focused on the platform architecture and requirements for the Deep Reinforcement Learning (DRL) module specific to pilot use cases.

AITIIP translated specifications from the MOSES and CABKA use cases into the requirements for D1.1. CABKA and IKOR provided detailed use-case-specific information to inform requirements and platform development. SIGMA worked on formalizing use-case specifications, analyzing hardware and software needs, and defining robotic skills necessary for the platform. IMR contributed by defining the reference architecture requirements, linking it to the DIH² system, and collaborating on the agile production cell design. IMR also provided specifications for D1.1 and supported translating requirements from WP4 to WP1.

NUTAI translated specifications from WP5 to WP1 to assist in understanding use-case needs. STER and ICPE contributed by providing detailed information about their respective use cases. STAM supported the translation of specifications from WP5 to WP1, with a particular focus on the ICPE use case. VICOM contributed to translating specifications from WP5 to WP1, ensuring the architecture aligned with the defined pilot cases and virtual gym interfaces. MOS provided specific use-case information.

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3.2 Work Package 2

WP number	2	Months	3-24
WP title	Robot cognitive capabilities		
Lead Partner	SIGMA		
Contributing partners	BFH, BIBA, MRNEC, AITIIP, DEUSTO, IKOR, NUTAI, STER, STAM, VICOM		

3.2.1 Objectives

The objectives of this WP are:

- To develop the robot modules architecture (models) that reflect the states of the product-human-environment.
- To develop a multi-modal robot perception for identifying accurately the visual-contact product features (to guarantee the final quality) and a multi-modal robot control for implementing a safe interaction.
- To develop dynamic robot programming techniques (cognitive task planner models) to automatically generate the robot tasks from CAD files and human demonstrations with dummy tools.
- To enable optimization of the perception-guided robot control model for a safe interaction with the product that guarantees its quality.
- To enable optimization of the human-robot collaboration model (cognitive human-robot collaboration model) for operational efficiency, natural coordination, and robustness under incidents.
- To develop a decision-making module based on Deep Reinforced Learning (DRL) for distributed coordination of autonomous and collaborative robots at scale.
- To set up Virtual Gym environment, by means of digital twins, for obtaining the optimal behaviour in robots.

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3.2.2 Activities

The activities in WP2 have been developed between M1 and M24, and the work has been finished and reported in previous documents (RP1 technical report, RP2 technical report, previous version of this deliverable). The outcomes are available in WP2 deliverables (D2.1 to D2.9).

Task 2.1 Robot model in the agile production environment (M3-M12): finished

This task focused on the formal specification of the use cases by defining their key elements: skills, primitives, and task planners. Using the Papyrus for Robotics tool, partners developed behaviour trees for each use case, which were essential for detailing task execution plans. The output of this work was compiled in D2.2, presenting the Robot Modules architecture.

During the second period, perception and control models were integrated into the ACROBA platform as skills and primitives. These were modular and reusable across different manufacturing tasks, such as bin-picking, inspection, and contour following. Unit tests validated the architecture and its performance.

Task 2.2 Multi-modal perception and control models (M6–M24): finished

Initial work included defining the necessary skills for the generic robotic cell, focusing on tasks such as pick-and-place. Different grasp synthesis approaches were tested, showing sensitivity to lighting conditions but demonstrating potential for small-object detection. Skills and primitives were formalized under the ROS1 framework, with plans to explore ROS Industrial solutions for robot-agnostic control.

By the second reporting period, the development of perception and control models was finalised. These models were implemented as modular skills and primitives within the ACROBA platform, making them reusable for various industrial scenarios. Specific tasks, such as bin-picking, inspection, and contour-following, were developed and validated. Safety functionalities for human interaction were also integrated, ensuring safe collaborative operations.

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Task 2.3 Cognitive task planner model (M6–M24): finished

Work began by analyzing requirements and creating a conceptual framework for the task planner. Plansys2 was selected as the planning tool due to its alignment with ROS2 and capabilities for task sequencing. Initial efforts focused on bridging ROS1 and ROS2 environments and prototyping behaviour trees for task execution.

During the second period, the task planner was implemented using ROS2, with behaviour trees facilitating task execution. A Human-Machine Interface (HMI) was introduced to allow users to interact with the planner dynamically, including starting, pausing, and modifying tasks. CAD-based task planning was applied to specific use cases, enabling the automation of assembly tasks.

Task 2.4. Cognitive human-robot collaboration model (M6-M24): finished

Preliminary work emphasized studying algorithms for human perception and activity recognition. Modalities such as video streams, sound, wearable devices, and inertial sensors were explored. OpenPose was used for real-time pose estimation, setting the groundwork for safe human-robot collaboration.

During the second period, a toolkit for human-robot collaboration was developed, including safety-related primitives for real-time human detection and tracking. A graphical user interface (GUI) allowed users to create, modify, and monitor tasks. This interface incorporated drag-and-drop modelling features and real-time feedback on task execution.

Task 2.5 Virtual Gym environment (M6-M24): finished

Initial work included evaluating simulation engines such as Gazebo and Unity, with both tested for feasibility. The framework for the Virtual Gym was developed, focusing on pick-and-place scenarios and ensuring alignment with WP3's generic cell definitions.

During the second period, the Virtual Gym was finalized using Unity as the simulation engine, supporting operations such as RGB and depth rendering, object picking, and material removal.

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ROS packages were developed for user interaction, and unit tests confirmed accuracy and consistency with real-world hardware.

Task 2.6 Deep Reinforcement Learning Module (M6-M24): finished

The DRL module's architecture was designed, focusing on integration with the ACROBA platform and the Virtual Gym. Preliminary experiments used simulation environments to test training robotic arms for tasks such as object picking and obstacle avoidance.

During the second period, the DRL module was fully implemented and integrated with the Virtual Gym and ACROBA platform. It included ROS-compliant interfaces and reinforcement learning algorithms for optimizing robotic tasks. Continuous integration tests ensured compatibility and stability for long-duration training sessions.

3.2.3 Partners' roles

In Work Package 2 (WP2), the lead partner was SIGMA, which managed all activities, including the development of control and perception algorithms, the skill-based framework, and the integration of robot cognitive capabilities into the ACROBA platform. During the first reporting period (M3-M12), DEUSTO played a significant role in leading the development of the DRL module architecture and task planner, as well as defining and formalizing robot models and use-case specifications. AITIIP contributed to developing the robot programming-by-demonstration concept, which included the use of sensorized dummy tools. BFH coordinated meetings, tasks, and unit tests while contributing to the cognitive task planner and its GUI development. NUTAI focused on defining human-robot collaboration modes and supported the integration of collaborative assembly pilot lines. BIBA worked on gathering data and analyzing collaborative pilot lines, particularly in developing HRC-related primitives and skills. VICOM initiated the development of the Virtual Gym environment, including the selection of the simulation engine and interface definitions for integration. MRNEC contributed to usability testing for the Virtual Gym and DRL module and designed functions for DRL agents in robot perception and control tasks. IKOR provided specific inputs related to their use case, supporting human-robot collaboration scenarios for their robotic cell. STER focused on integrating cognitive capabilities into lights-out manufacturing use cases, while STAM

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developed a design procedure to extract assembly parameters from CAD files for task planning.

In the second reporting period (M13-M24), SIGMA continued to lead, finalizing control and perception algorithms while integrating skills and primitives into the ACROBA platform. DEUSTO implemented the DRL module, conducted unit and integration tests, and provided support for the Virtual Gym and task planner, ensuring alignment with the DRL module. AITIIP coordinated the development of robot programming by CAD and dummy tools and managed the writing of related deliverables. BFH oversaw unit and integration tests, developed GUI elements for the task planner, and resolved WP-related issues. VICOM finalized the Virtual Gym, ensuring its compatibility with all pilot cases, and defined interfaces with other WP2 modules and the ACROBA architecture. MRNEC refined the DRL agent's functionality, tested it within the Virtual Gym, and ensured its integration into the ACROBA platform. NUTAI further supported collaborative pilot lines and refined definitions for human-robot collaboration modes. BIBA continued developing data-gathering tools and analyzing collaborative pilot lines, enhancing safety and HRC-related primitives. IKOR provided ongoing support for Virtual Gym scenarios and HRC modes tailored to their use case. STER continued integrating WP2 developments into lights-out manufacturing. STAM supported the application of CAD data in programming robot tasks, especially for the ICPE use case. IMR contributed by supporting integration and testing efforts for the agile robotic cell.

3.3 Work Package 3

WP number	**3**	**Months**	**10-30**
WP title	Agile production cell development, testing and refinement		
Lead Partner	IMR		
Contributing partners	BFH, BIBA, MREC, AITIIP, DEU, IKOR, SIGMA, NUTAI, STAM, ICPE, VICOM		

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3.3.1 Objectives

- To develop a reconfigurable sensorized robotic cell which integrates the robot, a suite for perception devices, a set of sensorized tools with the ACROBA architecture.
- To integrate a model based digital twin architecture, fast programming modules by human operators using sensorized tools, and the CPS systems that can support human safety and protection with the reconfigurable robotic cell.
- To develop guidelines and procedures for safe workplace design for agile production systems.
- To perform a set of standard robotic tasks, known as skills, representative of fully automated assembly and indeed collaborative assembly operations.

3.3.2 Activities

The activities in WP3 have been developed between M10 and M30. Tasks 3.1 to 3.4 officially closed during the RP2 (see RP2 technical report). However, tasks 3.3 and 3.4 continued their work on the active technical WPs during RP3 (i.e., WP4, WP5 and WP6).

Task 3.1 Development of a Reconfigurable Robotic Cell (M10-M24): finished

The development of a reconfigurable robotic cell officially started in Month 10. IMR initiated preliminary efforts earlier to streamline the process. Hardware and software for the robotic cell were defined to represent all relevant use cases. The robots selected included a collaborative UR5 and an industrial KUKA KR3, while sensors such as vision systems and force-torque sensors were included for interaction control. Specific generic tasks were also defined for the system, including 3D bin picking, part inspection, and contour following with force and vision control. Additionally, early progress was made on using sensorized dummy tools for fast programming. Initial testing of the ACROBA platform ensured successful installation and robot communication.

During the second reporting period, fully functional agile robotic cells for autonomous and collaborative production scenarios were developed and demonstrated at IMR's Mullingar facility. The setup included the industrial KUKA KR3 for automated tasks and the collaborative

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UR5 robot for human-robot interaction. These robots were equipped with Intel RealSense D435i and Zivid One+ cameras for object localization and reconstruction. The placement of robots, tools, and sensors was optimized to ensure smooth operation without obstructions or dark spots. The cells were designed to comply with relevant safety standards, including ISO 12100, ISO 13849, ISO 10218, and TS 15066.

Task 3.2 Integrated Cyber-Physical Protection Systems (M12-M24): finished

This task started at the end of the first period, and the focus was on transferring knowledge from generic skills into a common framework. Initial plans for integrating cognitive modules into the agile cell were defined. This work included outlining validation steps, establishing interfaces, and planning tests for later execution.

During the second reporting period, cognitive modules developed in WP2 were integrated into the agile cell. The integration process followed a cyclic approach, combining validation, refinement, and testing to ensure seamless compatibility. Unit tests and integration checks were successfully completed.

Task 3.3 Integrated Cyber-Physical Protection Systems (M10-M24): closed

For this task efforts centered on the design of integrated cyber-physical protection systems. A preliminary safety system design was developed, drawing on earlier patents to ensure a robust approach to human-robot collaboration.

During the second reporting period, significant progress was made on the cyber-physical systems, with a focus on human safety. Laser-based systems were implemented to replace earlier motion-capture technologies, which did not meet accuracy requirements. The new system tracked human positions in two dimensions and adjusted the robot's operating speed to ensure safety during collaboration.

Task 3.4 Human Factors and Behaviours and safety requirements (M15-M24): closed

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During the second reporting period, work on human factors and safety was initiated. The task involved analyzing user behaviour and defining additional safety requirements to enhance the system's ability to collaborate with human operators.

Tasks 3.1, 3.3, and 3.4 had additional progress and outcomes within the third reporting period. These tasks were initially executed between M10 and M30, officially closing during RP2. However, work on tasks 3.3 and 3.4 extended into RP3 through their integration with active technical WPs (WP4, WP5, and WP6). Workshops with ACROBA partners and safety associations, such as BGHM and DGUV, addressed challenges such as sensor limitations (accuracy, response time, redundancy, and plausibility) and safety concerns (non-functional safe, not certifiable). Actions were defined to refine the system for safe deployment in robotic applications, as recommended in reports D2.5 and D3.5.

The consortium (BIBA, BFH, and SIGMA) agreed to develop a new toolkit to enhance HRC-related capabilities, with BIBA leading the effort. The toolkit, available on the ACROBA GitHub repository, avoids extending the task planner's functionalities while supporting integration and execution of HRC capabilities. Outcomes are detailed in D2.5 and D3.5.

For Task 3.1, the ACROBA platform demonstrated a modular cognitive robotic system adaptable to various industrial scenarios under agile manufacturing principles. Two testbed generic cells—a standard industrial cell and an HRC collaborative cell—were developed to showcase platform functionalities. These cells reproduced industrial environments and allowed for iterative testing and refinement of the ACROBA architecture.

The platform, developed in ROS1 using Python and C++, features a structured architecture with primitives/skills accessible via API calls. Steps for the cell implementation included designing and building the cells, installing safety systems, integrating end-of-arm tools (EOAT), 3D camera systems, external PCs with ROS, and the ACROBA software platform. Figures 7 and 8 illustrate the industrial and collaborative cells developed at IMR.

Task 3.5 Framework testing and validation (M15-M48): Completed

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During the second reporting period, preparation for framework testing and validation began. The execution of integration tests for skills and functionalities was planned, and initial validation steps were carried out to ensure the system met the performance goals established earlier.

During the third reporting period the efforts were focused on integrating ACROBA modules into agile cells and evaluating their performance across tasks such as bin-picking, part inspection, contour mapping, and human-robot collaboration (HRC). These evaluations were conducted in real-world setups and a virtual gym environment, using predefined KPIs to validate the platform's effectiveness and robustness:

- **System Setup**: The ACROBA platform, operating on ROS1, required initial commissioning of 28 hours, which was reduced to 10 hours using the Unified Docker Platform (a 64%-time reduction). Collaborative robots integrated more easily with ROS1 than industrial robots.
- **Bin-Picking Benchmarking**: High success rates for unstacked parts: Cube (93.75%) and Mushroom (92.5%). Performance for stacked parts was lower, especially for Mushroom parts (60.8% success). Reconfiguration for product changes required 25 minutes.
- **Inspection Benchmarking**: Setup time reduced from ~10 to 2 hours using Docker. 3D reconstruction accuracy faced issues like stitching errors (~3mm), prompting recommendations for improved algorithms and error compensation.
- **Defect Detection**: Cube and Knob parts required 3 minutes 28 seconds per part for defect detection. Reconfiguration time for product change was 20 minutes. Limited parameter tuning for pass/fail criteria was identified as a key limitation.
- **Virtual Gym**: Enabled efficient testing of robotic operations, reducing deployment times to 1 hour. The virtual environment facilitated iterative testing and optimization.
- **Contour Mapping**: Dummy tools tracked CAD models for data collection, supporting task reproduction and intelligent training.
- **Human-Robot Collaboration (HRC)**: HRC systems were configured using ISO guidelines and adaptive controllers to monitor human presence and adjust robot speed. Safety zones and a dual-system backup solution were implemented for robust HRC operations.
- **Docker System**: Both industrial and collaborative cells were successfully tested within the Docker environment, showcasing modularity and ease of deployment.

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- **Bug Tracking**: Iterative platform updates and issues were documented using a bug tracking list to support systematic debugging and refinement.

Testing and validation efforts extended until M46, providing a robust template for ACROBA's deployment across industrial use cases.

3.3.3 Partners' roles

IMR served as the lead partner for WP3, taking charge of the overall development and demonstration of the agile robotic cells. They were responsible for designing and setting up the robotic cells, ensuring hardware and software integration, and managing compliance with relevant safety standards. IMR's facility hosted the functional agile production cells for both autonomous and collaborative production tasks.

BFH contributed to integrating the cognitive modules developed in WP2 into the agile production cell and provided support for testing and validation processes. They also helped refine interfaces between different modules to ensure smooth operation.

BIBA played a key role in the design and development of the safety systems. Their work included analyzing human-robot collaboration modes, contributing to safety concepts, and implementing solutions to meet safety requirements, such as dynamic monitoring of human positions.

DEUSTO supported the integration of WP2 outputs into the robotic cells. They worked on the implementation of task planner functionalities and provided additional contributions to integrating cognitive modules into the platform.

SIGMA focused on refining control and perception models for the agile production cell. They ensured that the developed skills and primitives aligned with the requirements of the robotic tasks and contributed to integrating these functionalities into the system.

NUTAI contributed to the design and implementation of collaborative assembly tasks. They provided input for the integration of human-robot collaboration functionalities and helped align the system's capabilities with the needs of real industrial use cases.

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STAM supported the design of robotic tools and jigs required for the production cell. They also worked on the development of methodologies for integrating digital twin functionalities and aligning the system with industrial requirements.

MRNEC assisted in testing and refining the modules integrated into the production cell. They provided expertise on validating the performance of the system under varying task conditions.

ICPE contributed to defining the requirements for their use case and provided inputs for testing specific robotic tasks within the production cell. Their work also included the alignment of system functionalities with industrial constraints.

VICOM supported the integration of virtual models and simulations into the production cell. They ensured that the interfaces for the digital twin and virtual gym were aligned with the system's overall architecture.

3.4 Work Package 4

WP number	4	Months	1-48
WP title	Lights Out Manufacturing Pilot lines		
Lead Partner	STER		
Contributing partners	BFH, MRNEC, AITIIP, DEUSTO, CABKA, SIGMA, IMR, MOS		

3.4.1 Objectives

- Design the pilot line use cases and risk assessment for fully automated agile production.
- Deployment, customization, and integration of the equipment in three production settings.
- Refine the pilot line based on continuous production.

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- Commissioning phase to refine pilot line based on continuous production.

3.4.2 Activities

Task 4.1 Pilot specification and preparation (M1-4): completed

Led by STER, the pilot specification and preparation phase started with defining the requirements and architecture of the pilot lines. This included workflows, hardware, and software for the three production environments: STER's end-to-end additive manufacturing, CABKA's large plastic piece production, and MOS's plastic production use case. Flowcharts and risk assessments were created to translate conceptual processes into practical tasks, providing a detailed understanding of each pilot line's operations.

The initial phase concluded with the completion of requirements in M4, as planned. From M5 to M16, feasibility studies on hardware were conducted due to the complexity of some technological components, necessitating an extension of the task timeline. Deliverables D4.6 (submitted in M10) and D4.7 (submitted in M16) documented the outcomes. D4.7 specifically provides a comprehensive conclusion, detailing metrics and feasibility tests for the pilot lines. For further details, please refer to the full report in D4.7.

The additional time allocated allowed the team to validate the readiness of hardware and processes, ensuring that the pilot specifications aligned with the project's broader objectives. This effort laid a strong foundation for subsequent implementation phases.

Task 4.2 Robotic infrastructure equipment upgrading and solution deployment (M20-M30): completed

During the second reporting period, AITIIP took the lead on upgrading robotic infrastructure and deploying solutions. For the SteriPack medical device pilot line, key equipment such as the printer, washer, oven, and robot were purchased and delivered. Additional hardware, including safety scanners, PCs, and cameras (Zivid and RealSense), was tested and configured onsite. IMR supported this task with consultation on infrastructure deployment, while CABKA and MOS contributed to defining workflows and planning feasibility studies for their respective pilot lines.

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Finally, during the third reporting period, the design and commissioning of equipment for the MOSES and CABKA cells were finalized, including the deployment of electrical and pneumatic wiring for cameras, spindles, safeties, and robot communications. These devices were validated independently and in conjunction with the ACROBA system. Additionally, the installation of the cell at AITIIP facilities was completed to integrate and test the skills developed in previous tasks. The STER medical device pilot line was also finalized, with support from IMR, involving the installation of a new robotic platform, integration of cameras and end-effectors, and full equipment validation both independently and with the ACROBA system. The results of these efforts were documented in Deliverable D4.4, submitted on June 30 (M30).

Task 4.3 Pilot line deployment, execution & refinement (M30-M48): completed

This task, completely executed during the third reporting period, was focused on the deployment, execution, and refinement of pilot lines in three large-scale industrial scenarios. The medical manufacturing use case was implemented in STER's production setting, while the plastic use cases for CABKA and MOSES were deployed at AITIIP facilities to streamline operations. The initial phase involved refining the transition from a generic cell to the industrial environment, optimizing the deployment process through adjustments and feasibility studies documented in D4.6 and D4.7.

After refinement, the final cell was commissioned by the use case provider and operated in a pseudo-production cycle as a batch production cell for the project's remainder. Data collection during this period supported further improvements to the ACROBA platform, enhancing its architecture based on real-world performance.

This task successfully demonstrated the ACROBA platform's ability to enable batch manufacturers to integrate advanced robot control modules without specialized programming expertise. The iterative refinement and data-driven adjustments ensured the platform's readiness for broader industrial adoption.

3.4.3 Partners' roles

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During RP1 (M1-M12), STER took the leading role as the Work Package leader, focusing on Task 4.1. STER was responsible for defining the specifications and preparation of the pilot lines, including workflows, hardware, and software requirements for their end-to-end medical device manufacturing pilot line. CABKA and MOS contributed to the definition and planning of their respective pilot lines: CABKA's large plastic product manufacturing and MOS's plastic production. AITIIP supported the identification of technologies and requirements for the MOSES and CABKA pilot lines. IMR provided initial input by supporting the feasibility studies for the integration of robotic systems and ensuring compatibility with the ACROBA platform. The efforts during this period laid the groundwork for understanding the technical and functional requirements of the pilot lines, with key deliverables submitted, including feasibility tests and workflow risk assessments.

During RP2 (M13-M24), AITIIP took a more prominent role in Task 4.2, leading the upgrading of robotic infrastructure and deployment solutions across the pilot lines. For STER's medical device pilot line, AITIIP facilitated the integration and testing of hardware components such as printers, washers, ovens, and collaborative robots, with STER managing the overall setup and ensuring the systems were operational. CABKA and MOS played key roles in defining the workflows and feasibility requirements for their specific production processes, ensuring alignment with the ACROBA platform. IMR supported the deployment by providing technical consultation on infrastructure upgrades and evaluating the pilot line readiness. VICOM contributed by ensuring compatibility between pilot line systems and the ACROBA platform.

During RP3 (M24-M48), the roles remained as they were being performed. STER as WP leader, contributed to T4.2 and T4.3, and managed the installation and execution of the medical devices pilot line. MOS contributed to T4.2 and T4.3 by defining specifications for workflows, hardware, and software, planning feasibility tests, and designing the electrical and mechanical components of the cell. AITIIP played a key role in T4.2 and T4.3 as the technology partner for MOSES and CABKA, defining specifications for workflows, hardware, and software, planning feasibility tests, and conducting individual device tests. DEUSTO provided support for deploying and operating the ACROBA platform, contributed feedback, and analyzed robotics tasks for developing DRL-generated skills. CABKA contributed to T4.2 and T4.3 by defining use case specifications and planning feasibility tests. SIGMA attended meetings, gave

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feedback, and supported hardware selection. IMR assisted in establishing the STER pilot line and contributed to T4.2 and T4.3 as a technology partner for STER by defining workflow, hardware, and software specifications, planning feasibility tests, and conducting individual device tests.

3.5 Work Package 5

WP number	**5**	**Months**	**1-48**
WP title	Collaborative Assembly Pilot Lines		
Lead Partner	NUTAI		
Contributing partners	BFH, BIBA, MRNEC, DEUSTO, IKOR, SIGMA, IMR, STAM, ICPE, VICOM		

3.5.1 Objectives

- Design of the collaborative assembly pilot lines and risk assessment for fully automated agile production.
- Upgrading the legacy equipment for the adoption of the ACROBA platform in the production settings.
- Deployment and integration of the ACROBA platform in two production settings: automated electronic component assembly and automated electric motor manufacture.
- Commissioning phase to refine pilot line based on continuous production.

3.5.2 Activities

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Task 5.1 Pilot specification and preparation (M1-M16): completed

During the first reporting period, the focus was on specifying the collaborative robotic cells. The aim was to define the requirements and specifications for the design and development of the collaborative robotic cells that will be used in pilot cases. This involved gathering input from the industrial partners and aligning with the needs of the use cases.

The work concentrated on defining the mechanical, electrical, and software components for the cells, ensuring they would meet the operational and safety requirements. Specific safety guidelines and considerations, based on ISO standards (such as ISO 10218-2), were addressed for the human-robot collaboration (HRC) scenarios. Deliverables provided a structured outline for the subsequent phases of implementation and development.

In the second reporting period, the activities conclude by finalizing the design specifications and security requirements for the collaborative robotic cells. The deliverables were refined and validated to ensure they met the expectations of the industrial use cases. Emphasis was placed on ensuring that the robotic cells adhered to the safety standards for collaborative tasks, including human-machine interaction scenarios.

Task 5.2 Robotic infrastructure upgrading and solution deployment (M20-M30): completed

During the second reporting period, the focus shifted to upgrading the legacy equipment and integrating the ACROBA platform into the production environments. At IKOR, the preparation included the configuration of robotic tools, such as grippers, sensors, and collaborative robotic systems, to execute pick-and-place tasks for PCB components. Extensive feasibility tests continued, evaluating the system's ability to adapt to different types of PCBs and ensuring cycle time improvements and error minimization. ICPE's pilot line progressed with preparations for automating the electric motor assembly process, including configuring the robotic cell layout, defining tasks, and ensuring compatibility with the ACROBA platform. Efforts were also made to ensure that the robotic systems could seamlessly interact with human operators while maintaining safety requirements.

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During the third reporting period, engineering designs were finalized to ensure optimal layouts for maximum efficiency. Programming tasks followed, prioritizing skill requirements for cell operations and refining these in collaboration with SIGMA. These skills were tested in the generic cell of WP3, with IMR documenting challenges for future steps in WP5.

Although delays in material delivery were anticipated, critical materials arrived on time for installation at partner facilities. Deliverable 5.3 provides detailed documentation of these developments. The designs faced challenges balancing compliance with Human-Robot Collaboration (HRC) norms and testing the ACROBA system. It was agreed that the pilot lines, while not fully ready for real industrial production, align closely with the project scope.

For HRC scenarios, a methodology to assess different options was developed by NUTAI and STAM. In IKOR's use case, the robot operates at a low safe speed to enable maximum collaboration, while ICPE's use case relies on laser curtains for operator detection. Both designs comply with HRC norms, and ACROBA's human detection skills were integrated and tested to enhance safety. Initial integration of the ACROBA platform into physical stations was completed, with basic operations successfully tested. KPIs for WP6 are being defined to evaluate system performance.

Task 5.3 Collaborative pilot lines demonstration (M30-M48): <u>completed</u>

This task, completely executed during the third reporting period, was focused on software development and integration, building on the engineering designs finalized in the previous task. Although the ACROBA framework was operational, integration of the final hardware began in M30 and was completed by M33. Following this, engineering partners refined software, identifying pending developments in a WP5 meeting. General-use skills requiring refinement were assigned to WP2 leaders, while specific skills were handled by engineering partners—NUTAI for IKOR's use case and STAM for ICPE's use case.

Challenges arose, such as the departure of a partner responsible for DRL skills, necessitating alternative solutions. Vicomtech provided support for vision-related and simulation tasks. By early 2024, basic specific skills were developed, and by M39 all partners were engaged in integration and refinement tasks. Testing began with individual skill validation, revealing

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inaccuracies that were resolved with assistance from Sigma and Vicomtech, despite limited support due to the absence of physical stations.

By M42, major issues were resolved, allowing partners to program sequences for the use cases. NUTAI developed the steps for picking and placing PCB components, while STAM programmed processes for coil winding and magnet bonding, incorporating error detection features for final validation. By M44, programming was complete, though STAM and ICPE faced vision-related challenges, and NUTAI and IKOR worked on calibration issues for high-precision tasks. By M45, stations were capable of completing full cycles, and partners focused on improving accuracy and reliability to meet project KPIs.

The final months were dedicated to reporting, compiling lessons learned, and preparing ACROBA for potential industrial applications, marking the successful conclusion of the task and project.

3.5.3 Partners' roles

Comentado [JH2]: Faltan los roles del RP3

NUTAI served as the Work Package leader, overseeing the overall progress and ensuring alignment with project objectives. VICOM led Task 5.1, focusing on the specification and preparation of pilot lines. VICOM coordinated the analysis of use cases, particularly defining workflows, safety studies, and risk assessments. IKOR actively contributed to specifying the requirements for their electronic component assembly pilot line, providing details on hardware, workflows, and the collaborative aspects of human-robot interaction. ICPE defined the scope and processes for their electric motor manufacturing use case, including feasibility studies. BFH, BIBA, and DEUSTO supported the analysis by contributing their expertise on robotics, cognitive modules, and safety systems. SIGMA assisted in evaluating technical feasibility, focusing on the integration of perception and control modules.

During the second reporting period, VICOM played a central role in Task 5.2, leading the upgrading of equipment and integration of the ACROBA platform into the collaborative pilot lines. IKOR focused on implementing robotic tools, including grippers and sensors, to execute pick-and-place tasks for their PCB assembly process. They conducted extensive feasibility tests to validate the hardware and software configuration. ICPE worked on automating the

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electric motor assembly process, contributing to the design and preparation of their robotic cell layout while ensuring task compatibility with ACROBA's modular platform. BFH, BIBA, and DEUSTO continued supporting the pilot lines by providing technical expertise in collaborative robotics and safety systems. SIGMA contributed by aligning perception and control algorithms with the specific requirements of both pilot lines.

3.6 Work Package 6

WP number	6	Months	3-48
WP title	Evaluation of performance and sustainability of the ACROBA framework		
Lead Partner	BFH		
Contributing partners	BIBA, MRNEC, AITIIP, DEUSTO, EMC2, CABKA, IKOR, SIGMA, IMR, NUTAI, STER, STAM, ICPE, VICOM, MOS, ROB		

3.6.1 Objectives

- To define and test scenarios with test plans for each of the defined use cases.
- To conduct the actual performance tests and evaluate the test results.
- To develop a set of benchmark tests for fully automated process for batch manufacturing and collaborative assembly tasks.
- To validate ACROBA Platform operation against the set of benchmark tests and benefits achieved. Setting-up and operating the ACROBA platform (Platform roll out roadmap).

3.6.2 Activities

Comentado [TW3]: @Congyu please update tasks 6.2, 6.3 and 6.4

Task 6.1 Coordination of test scenarios (M3-M14): completed

The ACROBA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017284.

Led by BFH, the team worked on organizing test scenarios for each defined use case. A kick-off meeting was held to define a detailed timeline, assign roles to partners, and distribute workloads. Requirements and KPIs from previous work packages, such as WP1 and WP4, were collected and mapped into a structured document, "Requirement_KPI_Test_Mapping_WP6." Partners, including DEUSTO, SIGMA, and AITIIP, reviewed and refined the requirements to ensure clarity and feasibility. Test scenarios and cases were then designed based on these requirements, establishing acceptance criteria for each test. A risk assessment was also performed, adding identified risks to the project's risk log, along with mitigation plans.

During the second period, work continued on refining test scenarios and test plans. Additional requirements and KPIs were integrated into the test mapping document. BFH organized meetings with partners to finalize baseline metrics for the pilot lines. These baselines formed the foundation for performance benchmarking and evaluation.

Task 6.2 Design and execution of a set of benchmark tests for Lights out and Collaborative manufacturing PLs (M30-M48): **completed.**

During the third reporting period, the defined test cases for five use cases (three lights-out and two collaborative scenarios) were executed, with KPIs calculated and evaluated. The benchmarking process consisted of two key comparisons:

1. **Benchmarking Against Current Manual Processes**: The tests demonstrated improvements in efficiency, consistency, and accuracy when transitioning from manual processes to automated solutions using the ACROBA platform.

2. **ACROBA Versus Conventional Automation**: The comparison, detailed in the D9.6, highlighted the advantages of the ACROBA platform in terms of agility, scalability, and reduced setup times. These benefits position ACROBA as a more flexible and cost-effective solution for agile production compared to traditional automation approaches.

The results will be shared via videos and posts to encourage future adoption of the ACROBA platform.

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Task 6.3 Quantifying benefit of ACROBA platform (Metrics and Performance levels) (M15-M48): completed.

Task 6.3, focused on quantifying the benefits of the ACROBA platform, evaluated its flexibility, scalability, and performance from M15 to M48. The testing involved five pilot lines, external production lines, and a generic cell, measuring KPIs to assess adaptability and replicability across various industrial scenarios.

Flexibility testing included scenarios such as product changes, process modifications, and hardware adjustments. These tests demonstrated the platform's ability to adapt to diverse operational requirements from STER, MOSES, CABKA, IKOR, and ICPE. However, certain limitations were observed under unplanned conditions. Scalability assessments were conducted through AOSLs (ACROBA Onsite Labs) at DIHs in Finland and Ireland, focusing on two external production lines: ENSTO and Croom Medical.

The ENSTO use case highlighted challenges with grasping irregularly shaped metallic parts, with inconsistent localization and bounding box estimation complicating the process. The average cycle time was approximately 5 minutes and 16 seconds, with a success rate of 40% and placement precision of 46%. In the Croom Medical use case, inspection tasks faced difficulties in achieving accurate 3D reconstruction, with the best scenario yielding 44% accuracy. Persistent misalignment issues limited defect detection capabilities, even with the use of advanced cameras like Zivid. Despite slight improvements, reconstruction quality remained below acceptable thresholds.

A performance comparison with the Halcon Vision System revealed significant differences. Halcon outperformed ACROBA in medical part inspections, delivering superior accuracy, speed (inspection time ~5 seconds), and flexibility, supported by advanced algorithms. In usability and accessibility tests, the ACROBA platform, leveraging Docker technology, significantly reduced commissioning and reprogramming times. For ENSTO, commissioning time dropped from ~10 hours 43 minutes to 1 hour 12 minutes, and reprogramming time from ~45 minutes to ~16 minutes. Similarly, for Croom Medical, commissioning time decreased from ~9 hours 52 minutes to 1 hour 7 minutes, and reprogramming time from ~39 minutes to ~10 minutes.

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The results indicate that while the ACROBA platform shows flexibility and scalability, its performance under certain conditions remains suboptimal. Issues such as grasping irregular parts and achieving precise 3D reconstruction for inspections need further development. Despite these challenges, the platform's modular design and ability to streamline processes demonstrate its potential for industrial applications. However, further optimization is essential for it to compete effectively with more established systems like Halcon.

Task 6.4 Platform roll out roadmap definition (M3-M48): <u>completed</u>

This task started with AITIIP leading the initial analysis. The team explored the feasibility of developing a single-entry point (SEP) that would allow third parties to adopt the ACROBA technology easily. Discussions with WP1 and WP3 partners were held to refine the SEP concept and examine options for implementing a virtual store to host ACROBA applications.

During the second reporting period, significant progress was made in defining the platform roll-out roadmap. AITIIP further refined the SEP concept, evaluating virtual platforms for distributing ACROBA applications. Discussions with partners explored strategies for ensuring platform scalability and user adoption.

During the third reporting period the Single Entry Point (SEP) was developed as a centralized hub to interface with potential users and clients interested in ACROBA's technologies and services. Designed to remain operational for at least five years beyond the project's conclusion, the SEP's development followed a collaborative approach. Initial workshops defined its key concepts, architecture, and branding, leading to the creation of three progressively improved versions, with version 3 representing the final iteration. Content contributions from ACROBA partners enriched each version, which has been published online.

Post-project, AITIIP will manage the SEP's operations until the joint venture is formally established, at which point responsibility will transfer to the new entity to ensure continued development and oversight.

As part of this task, the ACROBA Roll-out Roadmap was also developed. While no official deliverable was required before the project's conclusion, an internal publication of the roadmap

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was issued with updates every six months. It includes market studies and analysis of the project's most viable and mature exploitable outcomes. A strategy was developed to identify potential clients and explore further exploitation opportunities, including monitoring Horizon Europe topics for alignment with ACROBA's advancements.

Throughout the project's duration, updates to the roadmap and related strategies were made accessible on the consortium's collaborative platform for consultation and contributions. The outcomes of this task are documented in deliverables D6.9, D6.10, and D6.11.

3.6.3 Partners' roles

BFH served as the Work Package leader and took the primary responsibility for coordinating the overall activities in WP6. BFH led Task 6.1 by organizing the test scenarios and coordinating with partners to define requirements, KPIs, and baseline metrics. They also managed meetings to refine test plans, ensure clarity of KPIs, and create risk assessments to prepare for the testing phases. BFH was central in aligning WP6 activities with the ACROBA project goals, overseeing progress, and ensuring that all tasks adhered to the timeline.

AITIIP played a leading role in Task 6.4, focusing on defining the roadmap for the roll-out of the ACROBA platform. They initiated and refined the concept of the Single Entry Point (SEP) to facilitate the adoption of ACROBA technology by third parties. AITIIP conducted feasibility analyses and explored virtual platforms for distributing ACROBA applications. They collaborated with WP1 and WP3 partners to ensure technical alignment and scalability of the SEP.

DEUSTO contributed significantly to Task 6.1 by refining test requirements and KPIs. They worked alongside BFH to validate the feasibility and practicality of the defined metrics and test cases. DEUSTO's expertise ensured that the test scenarios addressed both technical and operational aspects of the ACROBA framework.

SIGMA supported the definition and mapping of requirements and KPIs within Task 6.1. They provided technical insights into performance testing and collaborated with BFH and DEUSTO

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to refine baseline metrics for pilot line evaluation. SIGMA also ensured that the KPIs aligned with the functionalities of the cognitive modules developed in WP2.

IMR contributed as a supporting partner, particularly in tasks related to testing preparation and the evaluation of flexibility and scalability for the agile robotic cells. Their role involved providing input on test requirements and aligning them with real-world industrial scenarios to validate the performance of the ACROBA framework.

3.7 Work Package 7

WP number	**7**	**Months**	**1-48**
WP title	Dissemination and Communication		
Lead Partner	EMC2		
Contributing partners	BFH, BIBA, MRNEC, AITIIP, DEUSTO, CABKA, IKOR, SIGMA, IMR, NUTAI, STER, STAM, ICPE, VICOM, MOS, ROB		

3.7.1 Objectives

- To create tools and engaging materials for promoting the project.
- To ensure the connection with the European DIH network and international community of practice.
- To disseminate and communicate project results to ensure the widespread adoption of robots.
- To carry out specific actions with the European DIH network to maximize impact.

3.7.2 Activities

Task 7.1 Creation of communication tools and materials (M1-M48): <u>complete</u>

The ACROBA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017284.

In this task the primary objective was to create and implement the Dissemination and Communication Plan. This plan outlined strategies for targeting various audiences, including industry, academia, and the broader public. Key activities included the launch of the project website, the creation of social media channels, and the development of promotional materials such as brochures, press releases, and branding assets. The website and social media platforms were used to communicate updates and milestones to stakeholders, while event monitoring began to identify opportunities for project dissemination. Partners started attending conferences and workshops to present the initial objectives of the ACROBA project.

During the second reporting period, the Dissemination and Communication Plan was updated to reflect progress and improve strategies based on initial feedback. Dissemination activities increased, with ACROBA being presented at more conferences, workshops, and exhibitions. The website and social media channels continued to be updated with news, milestones, and event participation, ensuring ongoing engagement with the target audience. Reports on dissemination progress were created to track participation in events and the impact of communication efforts.

During the third reporting period from M25 to M48, efforts under this task focused on enhancing the ACROBA project's online visibility through website updates and social media communication. The coordination and management of these activities were led by EMC2 as WP7 leader, who collected content from project partners and ensured it was effectively presented to strengthen the project's outreach.

The project website, **https://acrobaproject.eu/**, was maintained with regular updates, including the publication of articles and videos showcasing project outputs and activities. In the final project phase, the focus was on promoting hackathon-related content and producing videos highlighting the five pilot projects.

Social media played a key role in increasing visibility, with LinkedIn serving as the primary platform for raising awareness of website content and sharing updates about partner participation in relevant events such as fairs and conferences. By M48, the ACROBA LinkedIn account had 298 followers, reflecting significant growth due to consistent and targeted publications.

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Further details on these dissemination activities are documented in deliverable D7.5, the Final Dissemination and Communication Plan.

Task 7.2 Enhancing a community of practice (M1-M48): complete

For this task the focus was on identifying and engaging stakeholders to build a network around ACROBA technologies. A stakeholder database was created, consisting of over 300 contacts, including European Digital Innovation Hubs (EDIHs) and potential adopters. This task also initiated discussions about webinars and collaborations with existing DIH networks to create awareness about ACROBA and its potential for agile manufacturing. Preparatory work for future engagement activities included identifying topics for upcoming webinars and planning collaboration strategies.

During the second reporting period, the stakeholder database was expanded, and engagement with European DIHs intensified. Webinars were organized to promote the ACROBA platform's cognitive robotic capabilities and its applications in agile production environments. These webinars targeted industry representatives, developers, and other stakeholders, focusing on the technical aspects of the platform and showcasing its potential benefits. Collaborative opportunities with DIH networks were strengthened to increase ACROBA's visibility and impact.

During the third reporting period the ACROBA project effectively raised awareness through academic, industrial, and public engagement. By M48, it produced six published journal papers, eleven conference papers, two book chapters, and three PhD theses, with additional publications in progress. Academic partners trained students on ACROBA technologies through practical courses and lectures.

Industry dissemination included participation in key events like Automatica 2023, the European Robotics Forum 2024, and ROSConFR 2024, where workshops, demonstrations, and presentations highlighted the project's innovations. Robotics Days and open days at partner facilities showcased ACROBA pilot cells, providing hands-on demonstrations to stakeholders. The project also leveraged its website and LinkedIn account to share updates, increasing visibility and engagement.

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These efforts enhanced ACROBA's profile, reaching diverse audiences and fostering connections within the robotics and industrial automation communities.

Task 7.3 Organization of Acrobathons (M20-M48): complete

During the second reporting period the first ACROBA hackathon was successfully organized. The hackathon aimed to test and extend the functionalities of the ACROBA platform while involving developers, students, and researchers. Participants tackled technical challenges designed to evaluate the platform's capabilities in agile manufacturing scenarios. The event served as a practical demonstration of ACROBA's potential, promoting its adoption and fostering innovation among participants. The hackathon was supported by preparatory work that included defining challenges, logistical planning, and setting up evaluation criteria.

During the third reporting period, as recommended by the Project Officer and the reviewers after the review meeting held at M27, the partners have decided to reduce the number of hackathons initially planned (12) in order to redirect part of the dedicated budget and efforts towards activities that will target more directly potential users of the ACROBA solution – as for example the industrial fair Automatica 2023, the European Robotics Forum 2024 and the ROSConFr 2024.

The fIrst hackathon was organized by DEUSTO at M22. In the reporting period M25-48, 6 additional hackathons (BIBA, SIGMA, BFH, IMR, VICOMTECH) and 1 mega hackathon (ROB, VICOM, BIBA, BFH) were organized. A comprehensive overview is provided in D7.6 Report on the hackathons.

3.7.3 Partners' roles

EMC2 took the lead as the Work Package 7 leader, coordinating all dissemination, communication, and stakeholder engagement activities. EMC2 was responsible for developing the Dissemination and Communication Plan under Task 7.1, launching the project website, and creating communication tools like brochures, press releases, and branding materials. They also monitored event participation and the overall dissemination progress, compiling feedback to improve the communication strategy over time. In RP2, EMC2 continued

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overseeing updates to the communication plan, ensuring consistency across all project dissemination efforts.

IMR played a key role in Task 7.2 by supporting the creation and maintenance of the ACROBA stakeholder database. IMR provided the methodology for identifying and organizing over 300 stakeholders, particularly Digital Innovation Hubs (DIHs). They also contributed to webinar planning and engagement with DIH networks to promote ACROBA technologies.

DEUSTO contributed to Task 7.3, particularly in the preparation and organization of the hackathons during RP2. DEUSTO provided technical input for structuring the hackathon challenges and facilitated participant engagement.

BIBA, ROB, STAM, and VICOM were involved in supporting Task 7.3 during RP2, where they participated in planning and organizing the first hackathon. Their roles included defining technical challenges, logistics, and evaluation criteria to ensure the hackathon effectively demonstrated ACROBA's platform capabilities.

NUTAI supported Task 7.2 by contributing to stakeholder engagement activities, particularly in planning webinars and promoting synergies with European DIH networks.

3.8 Work Package 8

WP number	**8**	**Months**	**1-48**
WP title	Exploitation		
Lead Partner	ROB		
Contributing partners	BFH, BIBA, MRNEC, AITIIP, DEUSTO, EMC2, CABKA, IKOR, SIGMA, IMR, NUTAI, STER, STAM, ICPE, VICOM, MOS,		

3.8.1 Objectives

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- To lay the foundation for the ACROBA platform roll out and pave the way towards the exploitation of ACROBA outcomes in the industrial domain.
- To produce a methodology for the sustainability of ACROBA results while generating an economic impact assessment while considering impact.
- To set up joint exploitation vehicles to act as a catalyst for innovation in the Agile Production domain by offering realistic ACROBA exploitation corridors.
- To extend the impact of ACROBA solutions through partnership with other actions contributing to Agile Production in manufacturing SMEs.
- To influence the development of standards that support agile production.

3.8.2 Activities

Task 8.1 ACROBA exploitation strategy (M4-M48): complete

Work began with defining the initial exploitation strategy. ROB, as the task leader, participated in most WP meetings to stay informed about technical progress and identify potential exploitation opportunities. A survey was conducted to understand the innovation status, exploitation plans, and opportunities within the consortium. Additionally, a preliminary analysis of potential markets was initiated, alongside reviewing the Consortium Agreement and Grant Agreement to ensure alignment with obligations. The first steps toward defining the Intellectual Property Rights (IPR) strategy were also made. However, external engagement with industrial stakeholders was impacted by the COVID-19 situation, which limited attendance at physical events.

During the second reporting period, the first version of the ACROBA Exploitation Plan was released (D8.1) at Month 18. This plan outlined the key exploitation pathways, including commercial joint ventures and technology transfer strategies. ROB continued its coordination efforts, facilitating discussions with companies to identify real industrial use cases for ACROBA. A questionnaire was developed to assess SME readiness to adopt the platform and participate in ACROBA On-Site Labs. The plan also explored the potential for digital twins to enhance adoption among SMEs.

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Finally, on the last reporting period, deliverable 8.3, the Exploitation Strategy, was submitted, and Deliverable 8.4, the final version of the Exploitation Strategy, is scheduled for release in Month 48. Activities for AOSL Ensto in Finland are in the final stages, with testing and validation reported under WP6, while similar progress has been made for AOSL in Ireland (Croom Medical). AOSL Ensto also contributed two challenges for the final Hackathon held in Finland, achieving positive results. Much of the Exploitation Plan has been completed in collaboration with WP6, with corresponding reports available in Deliverable 6.9. A competitor analysis revealed no direct competitors in the market, only single-function tools that would need integration to create a comparable system.

Task 8.2 Sustainability Plan (M14-M21 & M31-M42): complete

During the second reporting period, the first version of the Sustainability Plan (D8.5) was delivered in Month 21. The report examined long-term economic impacts, including cost savings and production efficiency gains for SMEs adopting ACROBA. The plan emphasized the importance of maintaining the platform beyond the project's conclusion, with strategies for future funding and collaborations.

On the third reporting period, the Sustainability Plan has been completed, and Deliverable D8.6 has been submitted. ACROBA's sustainability actions have concentrated on establishing a joint-venture (JV) team, creating a startup, and developing its legal framework, involving partners AITIIP, BFH, IMR, NUTAI, and ROBOCOAST. The JV will continue after the project concludes, with legal rights for commercialization and further platform development. Due to project delays, JV actions are still ongoing. The Sustainability Plan has been developed alongside WP6, with Deliverable D6.11 introducing the Single-Entry Point.

Task 8.3 Fast-track Exploitation of Experiments in Agile Production (M14-M48): complete

During the second reporting period, discussions with IMR's industrial partners began to assess their agile production needs and readiness for adopting ACROBA technologies. However, progress was limited as the development of the ACROBA framework was still ongoing. IMR noted that the task would accelerate in the next reporting period.

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During the third reporting period, IMR has communicated with various agile manufacturers in Ireland to understand their processes and promote the adoption of the ACROBA platform under the AOSL initiative within WP6, where IMR is actively involved. Through a detailed evaluation of agile production use cases, IMR has identified key issues that can be addressed through further development of the platform, referred to as ACROBA 2.0. With the ACROBA platform now reaching a mature stage, it has garnered significant industry interest. IMR is set to host an upcoming ACROBAthon, which will provide valuable insights for rapid exploitation efforts. Additionally, IMR is collaborating with local system integrators and research institutes to develop two proposals focused on enhancing ACROBA's capabilities and optimizing its performance for complex agile production lines. These proposals have been prepared for use by the consortium and the joint venture.

Task 8.4 Standardisation Strategy (M14-M42): <u>complete</u>

BIBA led efforts to identify relevant standards applicable to the ACROBA project. A detailed strategy (D8.9) was submitted, outlining preparatory research, standardization potentials, and the importance of aligning ACROBA components with existing European and international standards. Contacts were initiated with German standardization bodies (e.g., DIN) and EU organizations to ensure ACROBA's compliance with evolving standards

The third reporting period began with gathering information on ACROBA components across development stages and outlining the fundamentals of standardization at various levels. A proposed standardization approach was detailed, including preparatory research, knowledge sharing, identifying standardization potentials, and emphasizing the importance of the strategy. Deliverable D8.9, the initial Standardisation Strategy report, was submitted and later refined based on reviewer feedback. This iteration focused on basic standardization principles and initial findings.

The final deliverable, D8.10, submitted in M48, builds on the majority of developed, tested, and validated ACROBA modules. Through iterative information gathering, partners gained insights into the project's implementations and innovations. A workshop held during the plenary meeting in Spain (June 2024) further refined achievable standardization activities.

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D8.10 includes a comprehensive list of standards and technical specifications used by the project, detailing each identified aspect of standardization. The report classifies these aspects (e.g., HRC, Design, Integration, Interoperability, Communication) and identifies 18 potential standardization aspects, providing strategies for each.

Task 8.5 IPR Management (M1-M42): complete

ROB initiated the management of intellectual property within the project. An IPR workshop was prepared to help partners understand the management of intellectual property rights and to clarify obligations under the Consortium Agreement. ROB also created the first version of the IPR database to track emerging innovations and IP contributions from partners. An IPR questionnaire was circulated to gather initial input on patenting or licensing requirements, and plans were made to strengthen partner engagement in IPR discussions.

During the third reporting period several workshops have been conducted with the consortium, focusing on exploitable results, open-source tools and licenses, trademarking, sustainability, and the joint venture license agreement. An EU Patent Attorney was consulted, and Deusto DRL conducted an analysis confirming no patent violations. The importance of patenting has been highlighted, with the EU Patent Attorney recommending Trade Secret protection and trademarking as viable options for safeguarding ACROBA's intellectual property. AITIIP has a patent pending for the Dummy Tool, and a licensing agreement is being developed between the consortium and the joint venture.

3.8.3 Partners' roles

ROB served as the leader of WP8 and took primary responsibility for coordinating all exploitation activities. In Task 8.1, ROB developed the initial Exploitation Strategy, conducting surveys to gather partners' exploitation plans and identifying innovation opportunities. They also led the creation of the IPR database and the IPR questionnaire. During RP2, ROB delivered the Exploitation Plan and conducted the first Freedom to Operate (FTO) analysis in Task 8.5. They organized workshops to guide partners in identifying and protecting project innovations, ensuring alignment with the Grant Agreement and Consortium Agreement.

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AITIIP played a key role in Task 8.2, contributing to the development of the Sustainability Plan. They gathered data on the economic impact of the ACROBA platform and explored strategies for maintaining the platform's adoption beyond the project's duration. AITIIP also worked on aligning sustainability goals with industrial needs, providing insights into future funding and collaboration opportunities.

BIBA led Task 8.4 on standardization, where they researched relevant European and international standards applicable to ACROBA. During RP2, BIBA prepared the Standardization Strategy and initiated contacts with organizations like DIN to ensure compliance and alignment of ACROBA components with existing standards.

IMR contributed primarily to Task 8.3 on the Fast-Track Exploitation of Experiments in Agile Production. IMR engaged with their industrial partners to assess agile production needs and identify opportunities for real-world adoption of ACROBA technologies. While progress was limited in RP2 due to ongoing framework development, IMR began discussions to facilitate testing and deployment in future periods.

All partners played a supporting role across various tasks by participating in the surveys, providing input for the IPR database, and contributing to the economic impact assessments. Their collaboration was essential to identifying the potential market value of ACROBA technologies and aligning exploitation activities with project outcomes.

3.9 Work Package 9

WP number	**9**	**Months**	**1-48**
WP title	Management		
Lead Partner	BFH		
Contributing partners	BIBA, MRNEC, AITIIP, DEUSTO, EMC2, CABKA, IKOR, SIGMA, IMR, NUTAI, STER, STAM, ICPE, VICOM, MOS, ROB		

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3.9.1 Objectives

WP9 deals with and manages all the activities within the project, including the monitoring, development and integration of the activities that are carried out. It covers the tasks related to project management and control activities to ensure that the project successfully meets its objectives in time and cost.

3.9.2 Activities

The management activities carried out since the start of the project include the preparation of deliverables, as well as the revision of other partner's document before the submission on the EU portal.

Task 9.1 Project Management (M1-M48): finished

At the beginning of the project execution this task established the foundational framework for the administrative, financial, and technical management of the project. Key activities included setting up project management procedures, quality plans, and organizational meetings to ensure coordination among consortium partners. Risks were identified, analyzed, and mitigated systematically during this period. No significant technical or financial deviations were reported.

During the second reporting period, management activities continued with a focus on coordination across work packages and addressing any technical deviations. Regular meetings were held, and project progress was monitored through KPIs and TRLs. Financial reporting and resource tracking were also carried out during this period.

Finally, during the third reporting period, monthly steering committee meetings and biannual financial reports were conducted. Deliverables were prepared, reviewed, and submitted, and two General Assemblies were held. Amendments to the project included extending its duration to 48 months and terminating a partner's participation. An onboarding strategy was developed to address challenges arising from staff turnover.

Task 9.2 Risk Management (M1-M48): finished

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Initially, risks were systematically identified and categorized. Mitigation strategies were proposed and aligned with project objectives to address potential threats. The methodology for risk tracking and reporting was established.

During the second reporting period, risk monitoring was enhanced with the identification of emerging risks. Mitigation plans were updated to reflect the evolving nature of the project. This included the systematic management of risks related to technical integration and partner collaboration.

At the third reporting period risk management activities included the creation of contingency plans for materialized risks and the identification of new risks aligned with Technology Readiness Levels (TRLs). Monthly risk meetings were introduced to monitor and address critical issues. Two risk-related deliverables were submitted, reflecting the status at M36 and M46.

Task 9.3 External experts' board (M4-M48): finished

Initial efforts were focused on identifying and engaging external experts to provide feedback on the project's progress and results. Public deliverables were selected to be shared with these experts.

On the second reporting period, the external experts provided initial feedback on the project. This feedback was shared with consortium members and incorporated into future activities where relevant.

Finally on the third reporting period, additional feedback was received from external experts, with suggestions to align project phases and further develop the ACROBA software. This input guided adjustments to the project's final stages and future considerations.

Task 9.4 Data Management (M1-M48): finished

The Data Management Plan was initiated and aligned with Horizon 2020's open data requirements. Preliminary assessments were conducted to ensure compliance with FAIR principles.

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During the second reporting period, the Data Management Plan was updated to reflect new developments in the project, ensuring it remained aligned with FAIR principles and Horizon 2020 guidelines.

Lately on the third reporting period, the final version of the Data Management Plan was prepared, confirming its alignment with EU requirements and evaluating its adequacy for project objectives. Updates ensured its relevance for the project's conclusion.

Task 9.5 Quality Management (M1-M48): finished

The Quality Assurance Plan and Project Handbook were introduced to establish the methodologies for ensuring high-quality deliverables and effective review processes throughout the project's lifecycle.

During the second reporting period, the quality assurance process was refined to address issues identified during deliverable reviews. Late submissions due to technical issues were minimized through improved coordination and communication.

Finally on the third reporting period, the established quality assurance methodology was followed to ensure high-quality deliverables. Any delays in submissions were mitigated through improved communication and support.

Task 9.6 Ethics Management (M1-M48): ongoing

From the beginning of the project, continuous collaboration with the external ethics advisor, Mr. Hans Graux (Timelex company). This ensured that the project met ethical guidelines and addressed any arising concerns effectively.

3.9.3 Partners' roles

BFH coordinated the project's technical and financial aspects and managed the consortium. They led the Steering Committee meetings, where all WP leaders (DEUSTO, SIGMA, IMR, STER, NUTAI, ROB and EMC2) and the risk manager (AITIIP) would meet monthly. Additionally, BFH ensured deliverable quality and monitored the project's financial progress. **AITIIP** as the risk manager, together with BFH and the involved partners, revised the risk log

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and methodology as well as led the monthly risk management meetings. **NUTAI** was leader of T9.3, managing the EEB. All partners participated in project meetings (General Assemblies, Review Meetings and other management related meetings) and prepared financial and technical reports.

3.10 Work Package 10

WP number	10	Months	1-48
WP title	Ethics requirements		
Lead Partner	BFH		
Contributing partners	n/a		

3.10.1 Objectives

The objective is to ensure compliance with the “ethics requirements” set out in this work package.

3.10.2 Activities

Activities carried out to ensure that the project is operated in accordance with the EU’s high standards for ethics, in compliance with the principle of responsible innovation. D10.1 provides an initial outline of ethics requirements, and of procedural measures already taken and still planned to ensure compliance of these standards. The measures proposed in this deliverable are thought to be able to satisfy EU’s requirements in relation to ethics. The document constitutes the AI guidelines generated by the members of ACROBA to assure the trustworthy of the project and the advances that will be achieved. ACROBA aims at promoting positive impact both commercially and societally, avoiding adverse impacts caused because of the transformation that this technology implies in the industry.

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To ensure effective implementation of the ethics guidelines, a support track is set up that will comprise validation of the piloting activities. This will also include a formal (but lightweight) data protection impact assessment (DPIA) that will satisfy the requirements of EU data protection law. In this way, the project remains legally compliant and can provide ethics best practices for comparable initiatives in the future.

Task 10.1 Ethics requirement (M1–M48): finished

At the beginning of the project the efforts was dedicated to establishing foundational ethical frameworks and guidelines. Deliverable D10.1, "Ethics Requirements," was created to outline key procedures, including data collection, informed consent templates, and policies for data transfer outside the EU. This phase emphasized the identification of Data Protection Officers (DPOs) among partners and engaged an external ethical advisor for guidance. The work included drafting requirements to mitigate privacy and security risks, addressing data anonymization, pseudonymization, and incidental findings. Regulatory monitoring, such as GDPR compliance and AI Act considerations, was also initiated during this period.

Building on the initial framework, during the second reporting period ACROBA implemented an **ethics compliance support track**. A standardized ethics compliance survey was distributed to partners engaging in data processing, enabling verification of their adherence to the requirements outlined in D10.1. This survey informed a Data Protection Impact Assessment (DPIA) that ensured GDPR compliance and further refined risk mitigation measures. The DPIA addressed privacy risks, defined new controls, and promoted adherence to ethical guidelines and regulations. These measures ensured the ethical alignment of the project's data handling and technology development.

In the final reporting period, ACROBA expanded to monitor and evaluate compliance with ethical guidelines. The standardized ethics compliance survey was reiterated, and updates were collected to verify consistent implementation of D10.1 requirements. Piloting partners ensured GDPR compliance through systematic data minimization, controlled data access, operator transparency, and robust data retention measures. Additionally, the DPIA was maintained, reflecting compliance with the evolving AI Act. Positive societal impacts were

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highlighted, including improved operator safety and reduced job market discrimination through automation, aligning the project's outputs with ethical and societal goals

3.10.3 Partners' roles

BFH worked continuously with subcontracted Ethics Advisor to expert help in specific ethic issues.

4 Follow-up of Recommendations and Comments from Previous Reviews

The second review meeting took place on 9th of March 2023. Our answer to the PMOC information letter was sent on 17th of May 2023 in order to provide our observations on it. An update in M48 has been provided as an Annex in D9.6 Project Management Report (v4).

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5 Use of resources

5.1 Use of resources

Consolidated data from M1-M41 has been collected from the management team. As the agreed interim report is in M48, after the submission of this deliverable, the actual figures of M42 to M48 will be presented in the final report.

The following data relates to M1-M41 internal financial reporting. In Table 3, it can be seen, for each work package, the cost planned detailed in the proposal budget (in orange), the new budget after the amendment (5th of June 2024) and the costs actually incurred by each type of cost (in green).

Table 3 WPs Planned vs Executed Budget

WPs	Technical Progress	PM reallocated	Person months (actual)	(A) Direct Personnel costs (planned)	Direct Personnel costs reallocated	(A) Direct Personnel costs (actual)	(B) Direct costs of sub-contracting (planned)	(B) Direct costs of sub-contracting (actual)	(D) Other direct costs (planned)	Other direct costs reallocated
WP1	100%	52.20	52.76	270,563.93	261,715.93	250,424.91	0.00	0.00	23,500.00	23,500.00
WP2	100%	142.20	142.01	882,192.94	817,399.45	817,135.20	0.00	0.00	20,800.00	8,500.00
WP3	100%	123.56	118.26	689,927.83	684,134.03	614,894.05	0.00	0.00	45,200.00	35,312.00
WP4	88%	184.08	169.12	741,531.11	888,975.36	870,174.04	0.00	0.00	372,333.00	352,333.00
WP5	88%	194.16	161.39	878,253.61	924,351.86	652,912.45	0.00	0.00	75,676.00	103,176.00
WP6	82%	108.23	85.08	621,940.57	598,892.67	451,445.25	0.00	0.00	152,350.00	100,680.00
WP7	82%	75.30	78.06	436,842.05	413,916.05	436,055.54	0.00	0.00	156,600.00	155,800.00
WP8	81%	81.50	62.50	424,668.59	413,224.59	369,178.33	0.00	0.00	51,300.00	54,300.00
WP9	85%	53.20	46.78	428,609.86	429,509.86	407,399.66	0.00	0.00	169,520.00	163,420.00
Total		1014.43	915.95	5,374,530.50	5,432,119.80	4,869,619.43	0.00	0.00	1,067,279.00	997,021.00

WPs	(D) Other direct costs (actual)	(E) Indirect costs (planned)	Indirect costs reallocated	(E) Indirect costs (actual)	Total Costs (planned)	Total costs reallocated	Total Costs (actual)	Earned Value (EV)	Cost Performance Index (CPI)	To Conclude Performance Index (TCPI)
WP1	2,182.45	73,515.98	71,303.98	63,151.87	367,579.92	356,519.92	315,759.23	356,519.92	1.13	0.00
WP2	17,819.82	225,748.24	206,474.86	223,498.63	1,128,741.18	1,032,374.32	1,043,693.81	1,032,374.32	0.99	0.00
WP3	23,555.80	183,781.96	179,861.51	167,134.48	918,909.79	899,307.54	798,062.35	899,307.54	1.13	0.00
WP4	267,437.66	278,466.03	310,327.09	268,218.63	1,392,330.14	1,551,635.45	1,422,014.67	1,361,083.73	0.96	1.47
WP5	81,530.10	238,482.40	256,881.96	222,878.51	1,192,412.02	1,284,409.82	918,053.22	1,126,675.28	1.23	0.43
WP6	14,016.79	193,572.64	174,893.17	118,521.34	967,863.21	874,465.84	581,827.60	715,645.94	1.23	0.54
WP7	91,444.58	148,360.51	142,429.01	126,352.98	741,802.56	712,145.06	659,375.21	585,609.71	0.89	2.40
WP8	19,008.94	118,992.15	116,881.15	93,467.87	594,960.74	584,405.74	485,234.13	470,701.72	0.97	1.15
WP9	87,863.44	149,532.46	148,232.46	122,511.36	747,662.32	741,162.32	619,078.94	631,875.19	1.02	0.90
Total	604,859.58	1,610,452.38	1,607,285.20	1,405,735.67	8,052,261.88	8,036,426.00	6,843,099.16	7,179,793.34	1.05	0.72

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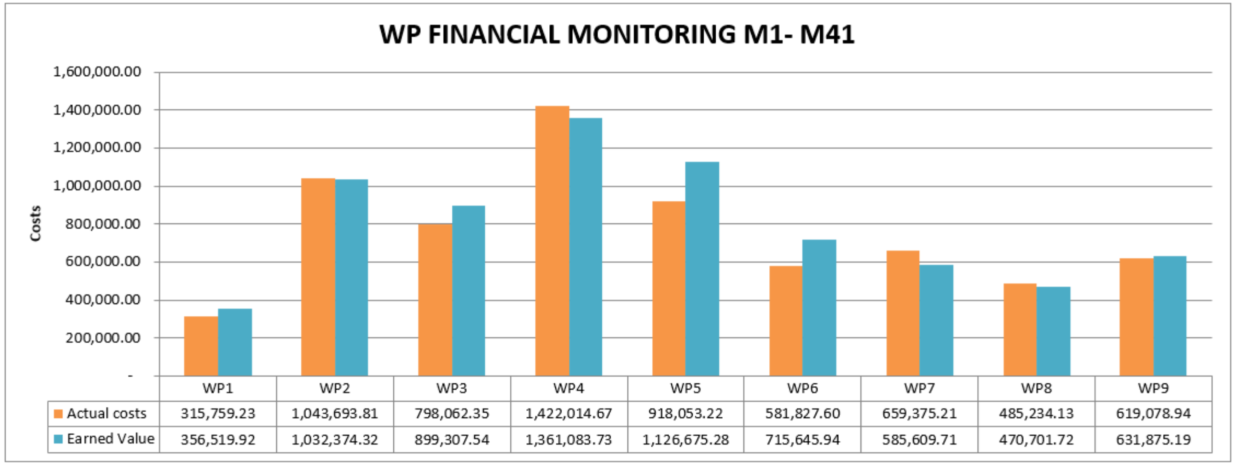
The earned value (EV) is the estimation of the costs in these 41 months if everything were as planned. The CPI index indicates that costs incurred in WP1, WP3, WP5, WP6 and WP9 are slightly lower than expected (in green), since they are greater than one (which indicates efficiency in the use of resources), however, WP2, WP4, WP7 and WP8 (in red) more is spent than it is worked, but the difference is small.

The following graphic in Figure 6 shows the results of the previous table, comparing the actual costs with the expected costs of this period:



	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9
Actual costs	315,759.23	1,043,693.81	798,062.35	1,422,014.67	918,053.22	581,827.60	659,375.21	485,234.13	619,078.94
Earned Value	356,519.92	1,032,374.32	899,307.54	1,361,083.73	1,126,675.28	715,645.94	585,609.71	470,701.72	631,875.19

Figure 6 WPs Financial Monitoring M1-M41

The following graph (Figure 7) compares the executed budget with respect to the total:

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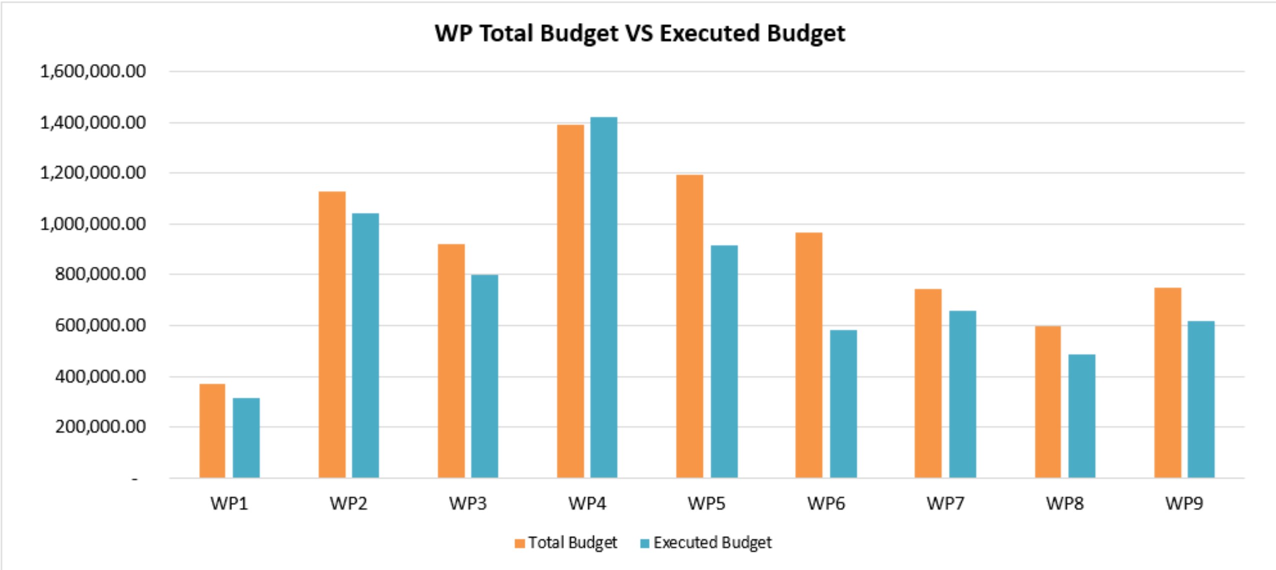

Figure 7 WPs Executed Budget vs Total Budget

In order to estimate the final costs at M48, a forecast of the last 7 months (M42-M48) was collected. The main conclusion is that, overall, the ACROBA project will incur in higher costs than budgeted (105%).

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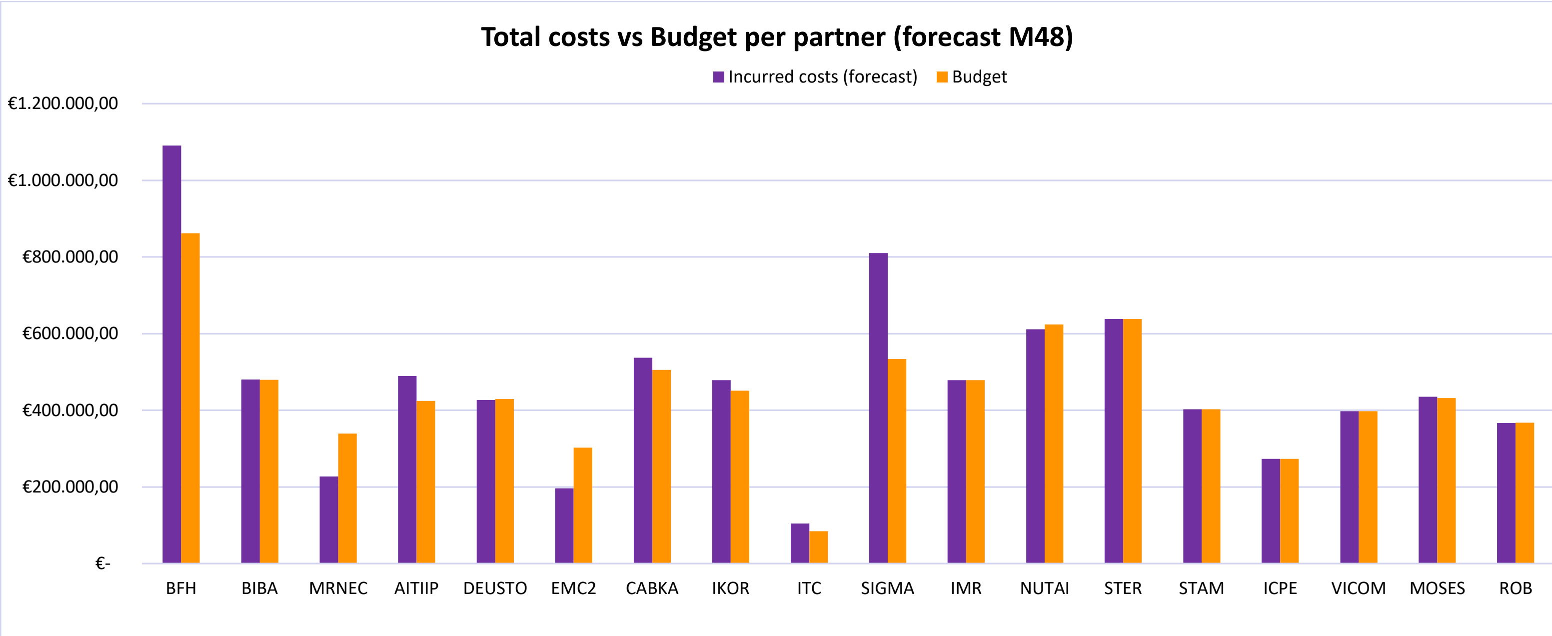

Figure 8 Total costs vs budget per partner (forecast M48)

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6 Conclusion

This project has been a complex and ambitious undertaking, marked by significant technical challenges and unforeseen obstacles that led to its extension. Despite these hurdles, we have worked diligently to address and resolve the issues encountered, effectively managing risks and ensuring progress toward our objectives. While some challenges and difficulties arose along the way, they have been successfully overcome through collaboration and perseverance. As we approach the conclusion of the project, only a few minor details remain pending at the time of completing this deliverable. We are confident that the project will be successfully finalized by the end of the year, meeting its intended goals and delivering meaningful outcomes.

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