Rail to Digital automated up to autonomous train operation

D4.1 – Automation Processes Collaboration Map

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EXECUTIVE SUMMARY

Deliverable D4.1 belongs to task 4.2 "Automation Processes Embassy" and its objective is to identify the main interactions between the Automation Process Cluster (APC) and other FP2 R2DATO clusters, and between the APC and other projects, both past and current in Europe's Rail. The document, therefore, also replicates this distinction, analysing both the external and internal interfaces.

In order to draw up the collaboration map, various meetings have been held with the main stakeholders.

One of the main interfaces corresponds to the Shift2Rail X2Rail-4 project given its relevant role in the development of the ATO GoA 3/4 specifications.

Other relevant interfaces are those with the Flagship Projects FP1 MOTIONAL for rail traffic management systems, FP5 TRANS4M-R for rail freight and FP6 FUTURE for regional lines.

Finally, the relationship with the System Pillar is understood as fundamental and an exchange process and common activities are established to maximize efficiency and obtain joint results.

The exchanges with other activities are centred around the milestones defined in the FP2 work program for the APC. Basically, the inputs for the APC (and specifically for the WP5, WP6, WP7 and WP8) must arrive at two specific points in time: M6 and M18. Finally, the results or even prototypes developed in the APC should be ready gradually from the M24.

It should also be noted that what is described in this document is a snapshot at the date of submission and that over the life of the project these interrelationships may change. However, deliverable D4.1 represents an excellent starting point to establish a clear picture of each other’s needs as well as a timeframe for the main exchanges and milestones.

ABBREVIATIONS AND ACRONYMS

APC	Automation Processes Cluster
APM	Automatic Process Manager
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ERTMS	European Rail Traffic Management System
EUG	ERTMS Users Group
GoA	Grade of Automation
FA	Flagship Area
FP	Flagship Project
MAWP	Multi-Annual Work Plan
MBSE	Model Based System Engineering
R2DATO	Rail to Digital automated up to autonomous train operation
STIP	Standardisation and TSI Input Plan
TAF	Telematic Applications for Freight (TSI)
TAP	Telematic Applications for Passenger (TSI)
TE	Technical Enabler
TRL	Technology Readiness Level
TSI	Technical Specification for Interoperability
WP	Work package

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The aim of FP2 R2DATO project (December 2022 to May 2026) is to take the major opportunity offered by digitalisation and automation of rail operation and to develop the Next Generation ATC and contribute to deliver scalable automation in train operations, up to GoA4 for 2030 (at the end of the Europe's Rail initiative), in order to maximise the infrastructure capacity on the existing rail networks, increase flexibility, punctuality and resilience while reducing operational costs. Tangible results of FP2 R2DATO are expected to be delivered by 2025, for key enabling technologies, contributing to the required transformation of the European railway system.

FP2 R2DATO corresponds to the first project of the Flagship Area 2 (FA2) described in the Multi-Annual Work Plan (MAWP)[1] of the Europe's Rail Joint Undertaking, which defines several Technical Enablers (TE) required to achieve the goals of FA2 for digital automated up to autonomous train operations in Europe. Such TEs have been grouped around six Clusters or subprojects as depicted in Figure 1.

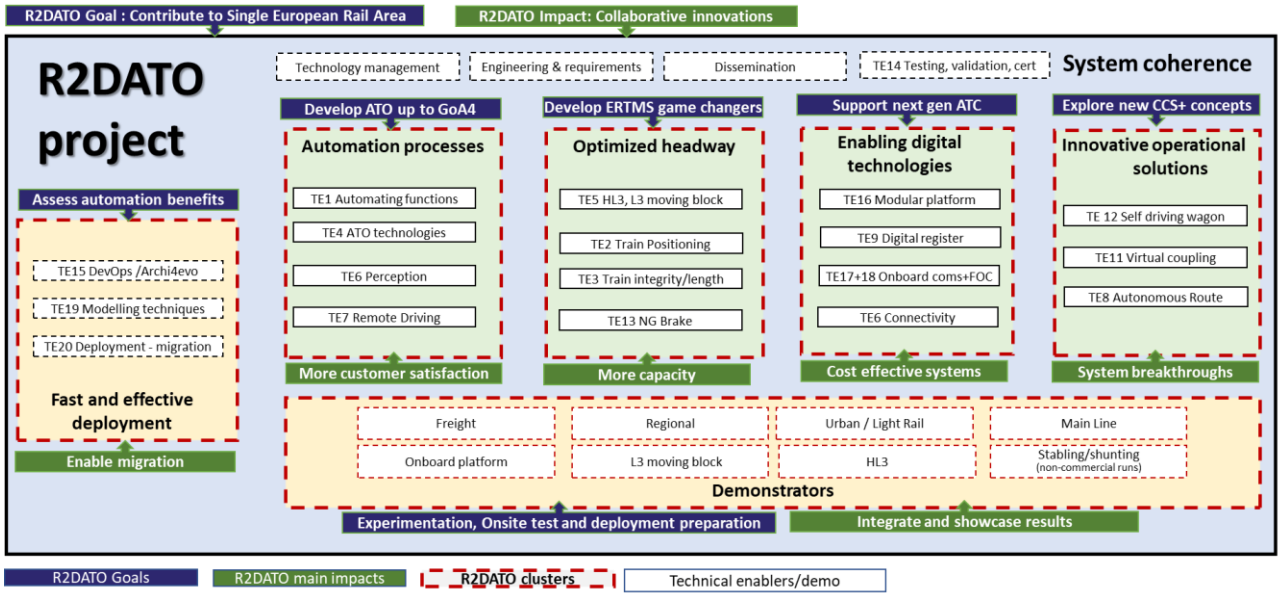

Figure 1: Project structure

One of the said Clusters, namely *Automation Processes*, integrates four TEs (TE1 – Automating Functions, TE4 – ATO Technology, TE6 – Perception, including the data factory, and TE7 – Remote Driving) which represent core technologies required for the automatization of the railway operations.

These TEs are developed in work packages (WP) numbers 5 to 12 of FP2 R2DATO to the level of laboratory validated prototypes (TRL4/5) ready for demonstration (TRL6/7) in the *Demonstrators* Cluster.

An additional work package (WP4) coordinates activities within the Cluster ensuring coherence and alignment, not only technically but also covering other aspects such as timing, risk management, development processes and quality.

[1] Adopted by Governing Board Decision n° 02/2022 and available at https://shift2rail.org/about-europes-rail/europes-rail-referencedocuments/europes-rail-key-documents

As the four TEs have strong links with other clusters and with other Europe's Rail activities defined in other Flagship Areas and therefore in their dedicated Projects e.g. FP1, FP5 or FP6, the second task of WP4 focuses on coordinating the interaction between the *Automation Processes* Cluster (APC) and such external activities. The name of this second task (Task 4.2) is hence *Automation Processes Embassy*.

The first activity of Task 4.2 is to identify the existing interdependencies inside FP2 R2DATO and then to focus on the external interfaces. This will create a collaboration map for the *Automation Processes Cluster*, defining the who, what and when with other parallel ongoing initiatives. This deliverable D4.1 aims at creating such map to support the daily interactions with the other initiatives during the project lifetime.

For that purpose the document is structured as follows.

Chapter 2, presents a general overview of the interfaces. The main background coming from Shift2Rail projects is described in chapter 3. Then, chapter 4 defines the FP2 R2DATO internal interdependencies, while in chapter 5 the interactions with external projects, including the System Pillar, are provided.

It must be noted that the content of this deliverable represents the snapshot of the expected collaborations at the date of publication. Along the project lifetime changes may be needed and new versions of this deliverable could be issued.

2 GENERAL OVERVIEW OF INTERFACES

The *Automation Processes* Cluster (APC) covers the Technical Enablers required to get to the target of achieving the automated to autonomous train operation in Europe. As automation is one of the main pillars of the future rail system, it means that the APC activities have strong links with other tasks and initiatives as depicted in Figure 2 on page 10.

The blue boxes represent the activities, as work packages (WP), included in APC, while the green boxes are other FP2 R2DATO activities. Finally, the orange boxes mean external projects.

Arrows describe an information or result flow between activities. For the specific case of prototypes, the member responsible for their delivery is also shown in the diagram.

For the sake of clarity, the interfaces with other Flagship Projects (FP) are not included in Figure 2, but detailed in chapter 5.

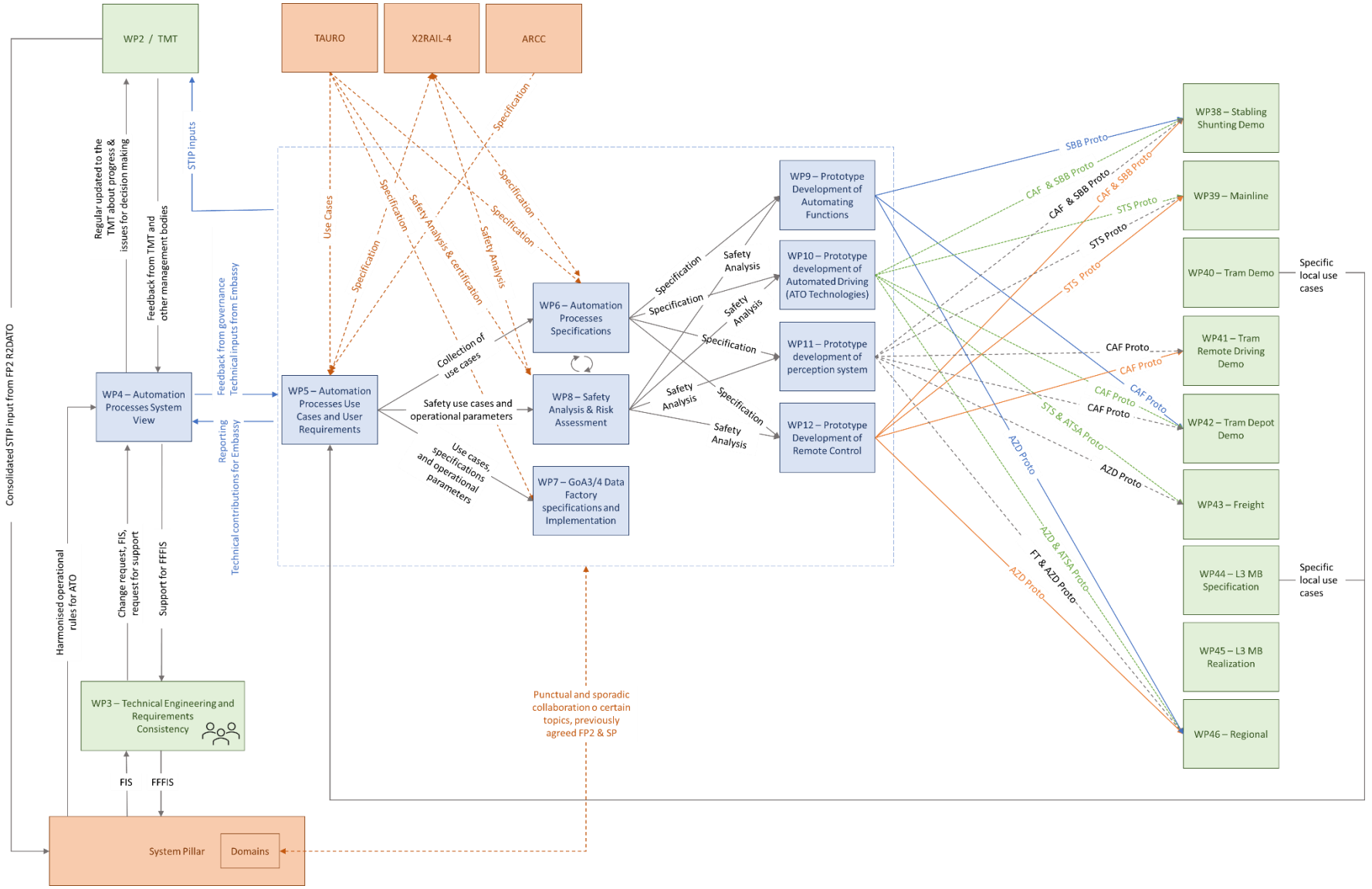

Figure 2: Interfaces

3 BACKGROUND FROM OTHER PROJECTS

3.1 X2RAIL-4

The EU-funded X2Rail-4 project (*Advanced signalling and automation system - Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers*) aims to bring to conclusion the research and development of some key technologies to foster innovations in the field of railway signalling, automation and supervision, as part of a longer term Shift2Rail IP2 strategy towards a flexible, real-time, intelligent traffic control management and decision support system. The actions undertaken in the scope of X2Rail-4 are related to the following specific objectives:

- On the basis of ERTMS/ETCS to implement (develop and test) the Automatic Driving up to the highest grade of automation GoA4 increasing line capacity, reducing operating costs, saving energy;
- To specify and prototype an innovative On-Board Train Integrity solution, capable of autonomous train tail detection, wired or wireless communication between the tail and the front cab, safe train integrity supervision (SIL-4 at system level) of train interruption, traditional power supply or energy harvesting solutions without the deployment of any fixed trackside equipment;
- To develop a standardised communication structure linking rail different business services and new software applications for Timetable Management and Traffic Control to support the operation of the new driving modes e. g. ATO;
- To develop and test new concept Object Controllers consisting of a solution scalable and flexible enough to fulfil different configurations and scenarios, where locally derived power and wireless communications, guaranteeing safety and security justifications, together with maximum de-centralisation are applied. Additionally, the higher bandwidths will be used for transmission of status reports / maintenance information and further required data.

The actions foreseen in X2Rail-4 are bringing to high readiness level (TRL) taking the results of previous X2Rail-1, X2Rail-2 and X2Rail-3 projects.

The main input expected from X2Rail-4 for FP2 R2DATO refers to the ATO GoA3/4 architecture, whose main highlights are listed below:

- System view of the Automated Train Operation (up to GoA4)
- Not limited to ATO components but addressing the “inner” train control loop and “outer” traffic control loop.
- It includes the interactions and functions exported to other subsystems which are part of the complete Railway System
- Delivery of full Operation Concept (principles, requirements, scenarios and glossary)
- Clarify the interactions between IMs and RUs (actors definition with their roles and processes).
- The logical architecture which specifies interchangeable building blocks with standard interfaces.

- Safety analysis based on the Operational Concept and on the System Requirement Specification
- MBSE approach with a focus on the Logical Architecture Layer of CAPELLA
- Alignment with OCORA, RCA, CONNECTA and SFERA
- Alignment with TSI outputs (CCS, LOC&PAS, TAF/TAP, OPE)
- IOP Reference Test Benches and Technical demonstrations on selected scenarios

While activities have already started within the APC, X2RAIL-4 activities will continue until December 2023. Meanwhile, an ATO transversal group is being set up in the System Pillar, that will be the single point of contact (in the context of System Pillar) of X2RAIL-4 and R2DATO for ATO related topics.

By the end of April 2023 X2Rail-4 releases a specification package mature enough to conform an initial reference point or baseline, namely Baseline 0 and composed by:

1. *ERTMS/ATO Operational Principles V1.9 – EUG Reference 12E108*
2. *X2Rail-4 deliverable D5.1 GoA3/4 Specification V0.2.4*
3. *X2Rail-4 Capella Model corresponding to the GoA3*/4 Specification V0.2.4

Having that relevant input, the agreed way forward in the context of APC is the following:

- Based on X2Rail-4 Baseline 0, R2DATO APC started a formal review process of:
    - ATO Operational Principles: needs, use cases and capabilities provided by the ERTMS User's Group
    - ATO up to GoA4 System Requirement Specification, provided by the ATO up to GoA4 working group,
- The formal review is done in the perspective of fulfilling the needs and objectives of FP2 R2DATO project. Participants provide in a review sheet, precise questions and comments in the frame of the objectives of the work package they participate to.
    - This review process is also taking place in the context of the System Pillar ATO transversal group, in its own perspective, meeting the System Pillar objectives.
- All review sheets of APC shall be completed for 07/07/2023 and provided to the APC System Engineer. Then, these review sheets shall be sent to X2Rail-4 by the System Engineer.
- From July to September 2023, X2Rail-4 team reviewed the sheets received from FP2 R2DATO.
- A workshop in September 2023 was organized, between X2Rail-4/ FP2 R2DATO/SP, to identify the topics that should be top priority for collaboration until December 2023.
    - X2Rail-4 has already completed the task of identifying topics that X2Rail-4 will manage until December 2023, and topics that to be covered by FP2 R2DATO and the System Pillar.

- This list could be updated during the September workshop, according to the result of the review process.
- APC work packages will contribute to the clarification of the identified open points during the review process, together with the X2Rail-4 team.
- This joint activity will enable a good endorsement of the X2Rail-4 Baseline 0 by FP2 R2DATO, a direct contribution to the improvement of the documents, and a smooth transfer of the activity in December 2023 at the closing of X2Rail-4.

- Between September and December 2023, X2Rail-4, FP2 R2DATO and the System Pillar meet at regular touchpoints, to check the status of the topics identified as priority in September.
- One intermediate touchpoint as a form of workshop took place on the 4th and 5th of October, leading to the following conclusions:
  - After the several exchanges between the participants it was agreed to endorse the X2Rail-4 ATO GoA3/4 SRS Baseline 0 as a common starting point for both System Pillar and FP2 R2DATO, and to perform the conflict (red flags) analysis and prioritisation until the next SP-FP2 meeting by the end of November.

The way forward proposal in synthetized in the planning below:

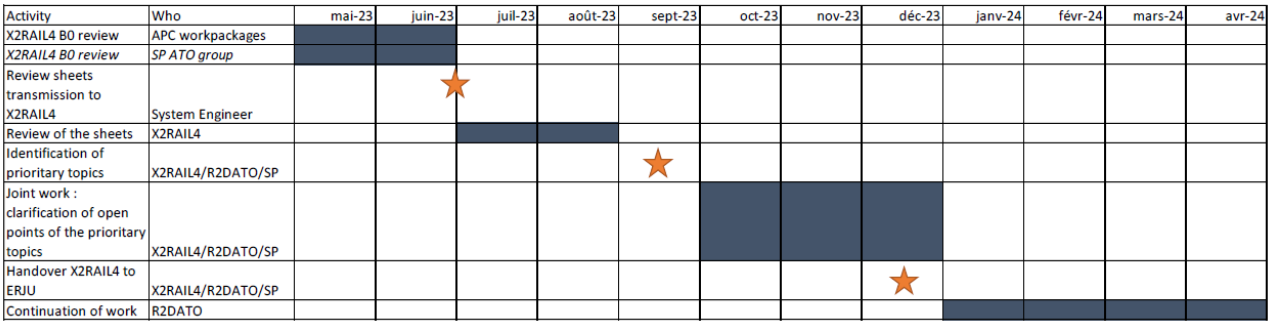

Figure 3: X2Rail-4 & FP2 R2DATO collaboration planning

Main aspects to be considered:

- X2Rail-4 ATO (up to GoA4) specification will end in 12/23.
- Needs to be continued in System Pillar and Innovation Pillar
  - Findings from the tests
  - Agreed open technical topics (will be formally defined)
  - Additional recommendations from safety and cyber
- The overlapping period between FP2 R2DATO and X2Rail-4 shall be carefully managed
  - Sharing permanently the on-going deliverables to FP2 members
  - Sharing the final results of pilot tests (including lessons learnt)
  - Sharing additional input from the System Pillar tasks and Innovation Pillar

- Proposal: to completely involve the ERJU as observer in the X2Rail-4 meetings. This shall concern the task leaders in the System Pillar and cluster/WP leaders in the Innovation Pillar (already aligned with the R2DATO WP5).

3.2 AUTOMATED RAIL CARGO CONSORTIUM

It has been identified that the only useful document coming from the Shift2Rail project Automated Rail Cargo Consortium (ARCC) of IP5 is the public summary of deliverable D1.7 (Documentation and Evaluation of GoA2 Freight Demonstrator Test Results in Specified Testing Scenarios, Proposal of Next Steps).

The complete deliverable is confidential but WP5 experts deem it not necessary to have it but such public summary.

3.3 TAURO

The EU-funded TAURO project (*Technologies for the AUtonomous Rail Operation*) aimed to shape the future of European rail transport by developing the leading-edge technologies required to make autonomous rail transport a reality. This was achieved by working on state-of-the-art systems for environmental perception, remote operation, automatic monitoring and diagnostics, and easing the transition to these new autonomous control systems.

TAURO addressed the topic “S2R-CFM-IPX-01-2020 – Advanced Functions towards Autonomous Trains” of the Europe’s Rail’s 2020 call for members. The work programme set out, in a very detailed manner, the challenges that needed to be addressed, breaking the work down into four work streams.

The high-level objective of TAURO was to identify, analyse and finally propose suitable founding technologies for the future European automated and autonomous rail transport, to be further developed, certified, and deployed through the activities planned in further stages in Europe’s Rail (i.e.. FP2 R2DATO project in the Flagship Area 2).

Indeed, TAURO was conceived as a kind of bridging project between the activities in the formerly known as Shift2Rail initiative and Europe’s Rail. For that reason, from the beginning a specific task was planned that focused on knowledge transfer.

The Steering Committee of TAURO decided to define three conditions to be accepted by FP2 R2DATO to get TAURO’s knowledge and results:

1. Confidential documents shall remain confidential and be managed as confidential as per the confidentiality clauses of FP2 R2DATO’s Consortium Agreement.
2. Access rights to confidential documents are granted for the only purpose of continuing the research and innovation activities on automated and autonomous train operation in FP2 R2DATO. No commercial use is allowed.
3. The Intellectual Property Rights of the documents and the results there described remain, in any case, with the TAURO members. In that sense, each deliverable and any public documents, including presentations and publications, that include or reproduce partially or

totally TAURO's results or parts of TAURO's documents shall include an acknowledgement stating the source and ownership of the concerned item.

The resulting knowledge process steps and timeline is depicted in Figure 4:

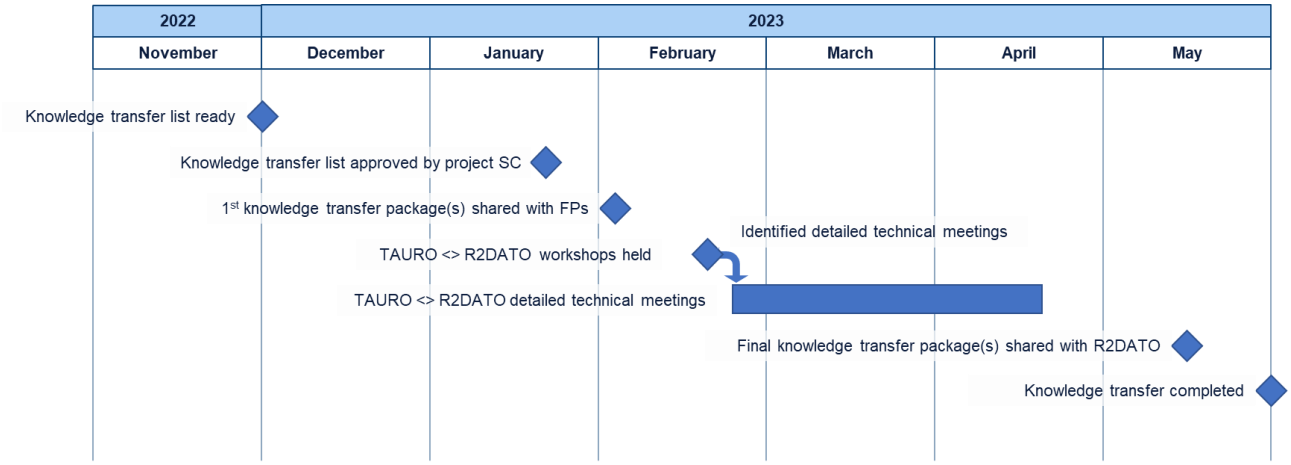

Figure 4: TAURO knowledge transfer process

The following table defines the list of documents selected by TAURO experts to be shared with FP2 RA2DATO:

	Origin							Expected destination	
ID	Code	WP	Title/Content	Type	Access	Status	Transfer Date	FP	WP
1	TAU-T1_1-D-CAF-082-04	WP1	D1.1 - Specification and Design of a Common Database for Rail AI Training and Testing	Deliverable	PU	Draft	06/02/2023	R2DATO	WP7
2	TAU-T1_1-D-CAF-082-05	WP1	D1.1 - Specification and Design of a Common Database for Rail AI Training and Testing	Deliverable	PU	Final	31/05/2023	R2DATO	WP7
3	TAU-T1_2-D-SMD-129-01	WP1	D1.2 – Proposal for Certification Methodology of Safe Functions based on Artificial Sense	Deliverable	PU	Draft	06/02/2023	R2DATO	WP6, WP8
4	TAU-T1_2-D-SMD-136-27	WP1	D1.2 – Proposal for Certification Methodology of Safe Functions based on Artificial Sense	Deliverable	PU	Final	31/05/2023	R2DATO	WP6, WP8
5	TAU-T1_3-T-CAF-005-02	WP1	T1.3 - Test Architecture Definition	Report	PU	Draft	06/02/2023	R2DATO	WP21, WP22
6	TAU-T1_3-D-RAI-006-01	WP1	T1.3 - State of the Art on SLAM and Digital Maps	Report	PU	Draft	06/02/2023	R2DATO	WP21, WP22
7	TAU-T1_3-D-CAF-007-04	WP1	D1.3 - Extension of Track Digital Maps	Deliverable	PU	Final	31/05/2023	R2DATO	WP21, WP22
8	TAU-T1_4-T-AZD-003-01	WP1	T1.4 - Use Case Structure	Report	PU	Draft	06/02/2023	R2DATO	WP5
9	TAU-T1_4-D-KNR-007-01	WP1	T1.4 - AI Enhanced Diagnostic Use Case	Report	PU	Draft	06/02/2023	R2DATO	WP5
10	TAU-T1_4-D-FTI-014-01	WP1	D1.4 - Applicability studies of environmental perception system	Deliverable	PU	Final	31/05/2023	R2DATO	WP5, WP6, WP11
11	TAU-T1_5-D-BTW-001-01	WP1	D1.5 - Requirement Specification for Indoor Environment Perception Systems	Deliverable	PU	Draft	06/02/2023	R2DATO	WP6
12	TAU-T1_5-D-BTW-001-03	WP1	D1.5 - Requirement Specification for Indoor Environment Perception Systems	Deliverable	PU	Final	31/05/2023	R2DATO	WP6
13	TAU-T1_6-D-BTW-001-03	WP1	D1.6 - Development of a system demonstrator and long-term assessment for the indoor environment perception system	Deliverable	PU	Final	31/05/2023	R2DATO	WP5, WP6, WP11
14	TAU-T2_1-D-CAF-004-08	WP2	D2.1 - Specification of the remote driving and command	Deliverable	PU	Final	06/02/2023	R2DATO	WP5, WP6

	Origin							Expected destination	
ID	Code	WP	Title/Content	Type	Access	Status	Transfer Date	FP	WP
15	TAU-T2_2-D-CAF-028-04	WP2	D2.2 - Detailed Architecture Solutions for Selected Use Cases	Deliverable	CO	Final	06/02/2023	R2DATO	WP6, WP8
16	TAU-T2_3-D-CAF-006-06	WP2	D2.3 - Application Profile for Remote Driving and Command	Deliverable	PU	Draft	06/02/2023	R2DATO	WP6, WP12
17	TAU-T2_3-D-CAF-006-10	WP2	D2.3 - Application Profile for Remote Driving and Command	Deliverable	PU	Final	31/05/2023	R2DATO	WP6, WP12
18	TAU-T3_1-D-FTI-039-02	WP3	D3.1 - Contribution to enhanced TCMS for automatic monitoring functionality regarding autonomous train	Deliverable	PU	Final	06/02/2023	R2DATO	WP5, WP6, WP9
19	TAU-T3_2-D-FTI-025-01	WP3	D3.1 - Contribution to enhanced TCMS for automatic diagnostic functionality regarding autonomous train	Deliverable	PU	Draft	06/02/2023	R2DATO	WP5, WP6, WP9
20	TAU-T3_2-D-FTI-025-02	WP3	D3.2 - Contribution to enhanced TCMS for automatic diagnostic functionality regarding autonomous train	Deliverable	PU	Final	31/05/2023	R2DATO	WP5, WP6, WP9
21	TAU-T4_1-D-ALS-023-01 TAU-T4_2-D-ALS-006-01	WP4	D4.2 - Updated GoA3/4 Specification	Deliverable	PU	Final	31/05/2023	R2DATO	WP6
22	TAU-T4_1-D-ALS-024-01 TAU-T4_2-D-ALS-007-01	WP4	D4.3 - GoA 3/4 model	Deliverable	CO	Final	31/05/2023	R2DATO	WP3, WP6
23	TAU-T4_3-D-DBA-010-01	WP4	D4.4 - ATO/TMS stability and headway analysis	Deliverable	PU	Final	31/05/2023	R2DATO	WP6
24	TAU-T5_2-B-CAF-014-01	WP5	Mid-term conference presentation	Presentation	PU	Final	06/02/2023	R2DATO	WP5, WP6, WP7, WP8
25	-	WP5	Final conference presentation	Presentation	PU	Final	31/05/2023	R2DATO	WP5, WP6, WP7, WP8
26	TAU-T5_2-I-CAF-021-01	WP5	T1.1 Paper - Common Data Management Platform for Artificial Sense Training and Testing for Railway Applications	Publication	CO	Final	06/02/2023	R2DATO	WP7
27	TAU-T5_3-B-CAF-006-01	WP5	T1.1 - AB Presentation	Presentation	CO	Final	06/02/2023	R2DATO	WP7
28	TAU-T5_3-B-SMO-013-01	WP5	T1.2 - AB Presentation	Presentation	CO	Final	31/01/2023	R2DATO	WP6, WP8
29	TAU-T5_3-B-CAF-007-01	WP5	T2.2 - AB Presentation	Presentation	CO	Final	06/02/2023	R2DATO	WP6
30	TAU-T5_3-B-CAF-008-01	WP5	T1.1 - AB Presentation Recording	Multimedia	CO	Final	06/02/2023	R2DATO	WP7
31	TAU-T5_3-B-CAF-010-01	WP5	T1.2 - AB Presentation Recording	Multimedia	CO	Final	31/01/2023	R2DATO	WP6, WP8
32	TAU-T5_3-B-CAF-009-01	WP5	T2.2 - AB Presentation Recording	Multimedia	CO	Final	06/02/2023	R2DATO	WP6

	Origin							Expected destination	
ID	Code	WP	Title/Content	Type	Access	Status	Transfer Date	FP	WP
33	TAU-T5_3-B-CAF-011-01	WP5	ATO Risk Presentation Recording	Multimedia	CO	Final	06/02/2023	R2DATO	WP6, WP8
34	TAU-T5_3-B-CAF-012-01	WP5	ATO Risk Presentation	Presentation	CO	Final	06/02/2023	R2DATO	WP6, WP8

Table 1: TAURO background for APC

3.4 Quality and Timely Delivery of Inputs

At the start of the project there was some uncertainty about the availability and quality of the results from the external projects described in this chapter. However, at the date of this version of deliverable D4.1, right after the review performed during the Maturity Checkpoint #1, it can be concluded that this risk has not materialised.

The successful transfer of knowledge between the previous key projects (mainly TAURO and X2Rail-4) to the Automation Processes Cluster has been possible because their reference persons also play relevant roles in R2DATO: In particular the TAURO Coordinator is the cluster Leader, and the main contributor to the X2Rail-4 ATO GoA3/4 SRS is the cluster System Engineer.

4 R2DATO INTERNAL INTERFACES

Chapter 4 of the Automation Processes Collaboration Map has its focus on providing insight in the internal R2DATO interfaces and to understand the required information and/or output flows. Two distinctions can be made in this section. Firstly, interfaces between 'cluster 1 – Automation Processes' and 'cluster 6 – Demonstrators'. This will be discussed in section 4.1. Section 4.2 will focus on the interface between WP3 with WP4.

4.1 Demonstrator Cluster

Goal of this section is to provide insight in the required information and/or output flow between cluster 1 – Automation Processes and cluster 6 – Demonstrators. The relation between both clusters is working both ways. Cluster 1 has to provide input in the form of deliverables to cluster 6, so that the WPs in cluster 6 are able to create their demonstrators on these inputs. On the other hand, the WPs in cluster 6 need to define what they need in order to conduct their demonstrators. In the below two tables is the overview of the Work Packages that are involved in both cluster 1 and cluster 6, this information is derived from the Grant Agreement (Project 101102001 — FP2 - R2DATO).

Cluster 1 – Automation Processes

WP4	Automation Processes System View CAF
WP5	Automation Processes Use Cases & User requirements NS
WP6	Automation Processes Specification SMO
WP7	GoA3/4 Data Factory specifications and implementation DB
WP8	Safety Analysis and Risk Assessment FT
WP9	Prototype Development of Automation Functions AZD
WP10	Prototype Development of Automated Driving (ATO Technologies) HITACHI
WP11	Prototype Development of Perception System FT
WP12	Prototype Development of Remote Control HITACHI

Cluster 6 – Demonstrators

WP36	Onboard Platform Demonstrator DB
WP37	ETCS HL3 Deployment Strategies PRORAIL
WP38	Automatic Stabling, Shunting, and Non-commercial runs Demonstrator NS
WP39	ATO over ERTMS demonstration on mainline FSI
WP40	Autonomous Tram Demonstrator CAF
WP41	Remote Driving and Telecommand Demonstrator CAF
WP42	Tramway autonomous movements in depot demonstrator CAF
WP43	Freight Demonstrator SNCF
WP44	Moving Block ETCS L3 Demonstrator – Specification DB
WP45	Moving Block ETCS L3 Demonstrator – Realization DB
WP46	Regional line demonstrations AZD

Within cluster 1 (APC), the following technical enablers are covered according to the mapping on page 260 of the Grand Agreement: TE01 Automating Functions, TE04 ATO Technology, TE06 Perception, TE06.1 Data Factory and TE07 Remote Driving. These TEs have been mapped against the demonstrators from cluster 6 in the Grant Agreement. Below is an adapted version of this table. As can be seen, all the technical enablers are represented in the demonstrators. However, on the demonstrator side, demonstrator 6, L3 Moving Block is not covering any TE from cluster 1.

			Demonstrators							
TE *no.*	R2DATO activities		D1: Freight	D2: Regional	D3: Urban	D4: Main line	D5: ETCS HL3	D6: L3 MB	D7: Stabling & Shunting	D8: Onboard Platform
			WP43	WP46	WP40, WP41, WP42	WP39	WP37	WP44, WP45	WP38	WP36
TE1	T5.1, T6.1, T6.2, T8.1, WP9	Automatic functions		X	X (IKAA)				X	
TE4	T5.3, T6.5, T8.2, WP10	ATO technology	X	X	X	X			X	
TE6	T5.2, T6.3, T6.4, T8.3, WP11	Perception	X	X	X	X			X	
TE6.1	WP7	Data factory	X							
TE7	T5.4, T6.5, T6.6, T8.4, WP12	Remote driving		X	X	X			X	

In addition to the mapping of the Technical Enablers, there is also a stream of information and output between the two clusters. In order to map the streams of inputs and outputs between the different WPs in FP2, the Interdependencies Matrix was created by partners from all WPs. Based on this matrix, inputs and outputs between cluster 1 and cluster 6 have also been identified. In the table on the next page an adapted version of the interdependency matrix can be found that solely focus on cluster 1 and cluster 6.

Rows represent the WP of cluster 1 delivering inputs (*from*) while columns are the WP of cluster 6 receiving such inputs.

Besides the table, the following generic approach is applied: Any input concerning the use cases which the demonstrators will develop should be available for M6 (MS1) for assessment and supporting prioritisation in WP5. Required prototypes will be delivered back to them accordingly to the Table 3 in page 24.

To / From	Dead-line	WP36	WP37	WP38	WP39	WP40, WP41, WP42	WP43	WP44	WP45	WP46
WP5	M12	WP5: Provide use cases and operational needs for migration strategy M12			WP5: Use cases (for safe perception systems) and operational needs, specifications and operational parameters	WP5: Defining (safety) use cases and operational parameters Operational rules and use cases aimed at harmonization	WP5: Use cases (for safe perception systems) and operational needs, specifications and operational parameters	WP5: Use cases for safe perception systems, definition of Use Cases, operational parameters and scenarios for remote driving Review of specification for ATO GoA3-4 technology	WP5: Defining (safety) use cases and operational parameters Review of specification for ATO GoA3-4 technology Use cases for safe perception systems	WP5: Defining (safety) use cases and operational parameters Review of specification for ATO GoA3-4 technology use cases for safe perception systems
WP6	M36						WP6: Specifications of TE and interfaces of ATO GoA34.			
WP7	M41						WP7: Define data format requirements for data factory. Data for virtual certification on Test Bench			
WP8	M24			WP8: output may be required for derogation demonstrator trainset.						
WP9	M42				WP9: Analysis of migration and deployment strategies. Architecture for automated functions. Documentation of					WP9: Analysis of migration and deployment strategies. Architecture for automated functions. Documentation of

From \ To	Dead-line	WP36	WP37	WP38	WP39	WP40, WP41, WP42	WP43	WP44	WP45	WP46
					functional prototype, Test-Report.					functional prototype, Test-Report.
WP10	M42			WP10: CAF instance of TE4, will be used to derive the Demonstrator	WP10: Hitachi instance of TE4, will be used to derive the Demonstrator	WP10: CAF instance of TE4, will be used to derive the Demonstrator	WP10: Hitachi and ATSA prototype of TE4, will be used to derive the Demonstrator		WP10: CAF instance of TE4, will be used to derive the Demonstrator	WP10: AZD and ATSA instances of TE4, will be used to derive the Demonstrator
WP11	M42			WP11: TE6 for Stabling & Shunting Demonstrator	WP11: TE6 for Mainline Demonstrator		WP11: AZD Prototype of TE6 for Freight Demonstrator			WP11: TE6 for Regional for ATO over ETCS Demonstator
WP12	M42				WP12: Hitachi instance of TE7, will be used to derive the Demonstrator	WP12: CAF instance of TE7, will be used to derive the Demonstrator		WP12: CAF instance of TE7, will be used to derive the Demonstrator		WP12: AZD instances of TE7, will be used to derive the Demonstrator

Table 2: Interdependencies matrix

The following table describes the expected delivery of validated[2] prototypes by APC for being integrated in the demonstrators:

	WP38 - Stabling and Shunting				WP39 - Mainline		WP41 - Tram RC		WP42 - Tram Depot		WP43 -Freight				WP46 - Regional			
	Demo NS		Demo SBB		Demo FSI		Demo SPV		Demo SPV		Demo SNCF				Demo AZD			
	Who	When	Who	When	Who	When	Who	When	Who	When	Who	When	Who	When	Who	When	Who	When
WP7 - GoA2/4 Data Factory Specifications and Implementation											SNCF	Q3/Q4 2024						
WP9 - Prototype Development of Automating Functions			SBB	N/A (testing in switzerland, no dependance APC inputs)					CAF (IKAA)	Q4 2025					AZD	Q4/2024		
WP10 - Prototype Development of Automated Driving (ATO Technologies)	CAF	Q3/4 2024	SBB	N/A (testing in switzerland, no dependance APC inputs)	STS	Q4 2025			CAF	Q4 2025	STS	Q3/Q4 2024	ATSA	Q3/Q4 2024	AZD	Q4/2024	ATSA	Q4/2024
WP11 - Prototype Development of Perception Systems	CAF	Q3/4 2024	SBB	N/A (testing in switzerland, no dependance APC inputs)	STS	Q4 2025	CAF	Q4 2023	CAF	Q4 2025	AZD	Q3/Q4 2024	ATSA	Q3/Q4 2024	AZD	Q4/2024	FT	Q4/2024
WP12 - Prototype Development of Remote Control	CAF	Q3/4 2024	SBB	N/A (testing in switzerland, no dependance APC inputs)	STS	Q4 2025	CAF	Q4 2023							AZD	Q4/2024		

Table 3: Delivery of prototypes to the Demonstrators Cluster

Each cell represents the delivery of a prototype, indicating which partner is responsible for and the expected timeframe.

[2] Validated means successful testing in the laboratory under representative conditions (TRL4 or TRL5), enabling further testing in the field to reach TRL6 and above.

4.2 WP3

FP2 R2DATO WP3 ensures the coherence among the project activities and consolidates the inputs concerning architecture. Moreover, WP3 drives the interface between FP2 R2DATO and the System Pillar.

The reference role between the Automation Processes Cluster (APC) and WP3 is the System Engineer, who will take care of implementing the interface and of orchestrating the exchanges.

Figure 5 shows an overview of the interaction between the clusters and the System Pillar through the WP3. WP3 is organising a baseline management process that will contribute to relevant freezing points for the overall specifications of FP2 R2DATO, guide branching and help the identification and resolution of gaps between the project and the System Pillar.

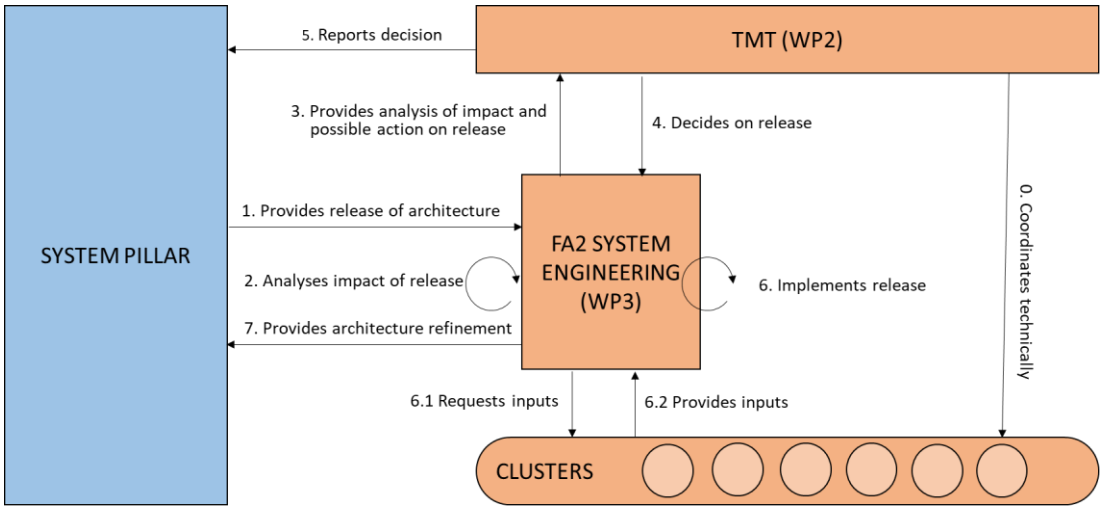

Figure 5: Interfaces with WP3 and exchange process with the System Pillar

The core part of APC, from the architecture point of view, relies on the ATO GoA3/4 architecture inherited from X2Rail-4, which will be fully handed over to FP2 R2DATO in December 2023 under its baseline 2.

This architecture comprises not only the ATO (understood as the ATO and the APM logical components) but its interfaces with other components such as the ATP, the train location or the repository among other. Hence it is needed that WP3 masters the ATO GoA3/4 architecture from baseline 2 and evolves it to baseline 3 and above with the inputs of APC and other clusters of FP2 R2DATO.

In that sense the role of the APC System Engineer is crucial in order to ensure coherence and to align with the other contributors to the overall R2DATO architecture.

5 APC EXTERNAL INTERFACES

This chapter describes the interfaces between the Automation Processes Cluster (APC) and the ongoing Flagship Projects (FP) besides FP2 R2DATO. The projects with which APC will have stronger links are FP1 MOTIONAL, FP5 TRANSF4M-R and FP6 FUTURE.

5.1 FP1 MOTIONAL

Although there is no combined FP1 – FP2 demonstrator in the first wave of projects (i.e. MOTIONAL and R2DATO), preparatory works are already planned in the next four years.

Such activities concern the implementation of a simulator in FP1 MOTIONAL for which a proper understanding of the ATO behaviour must be acquired.

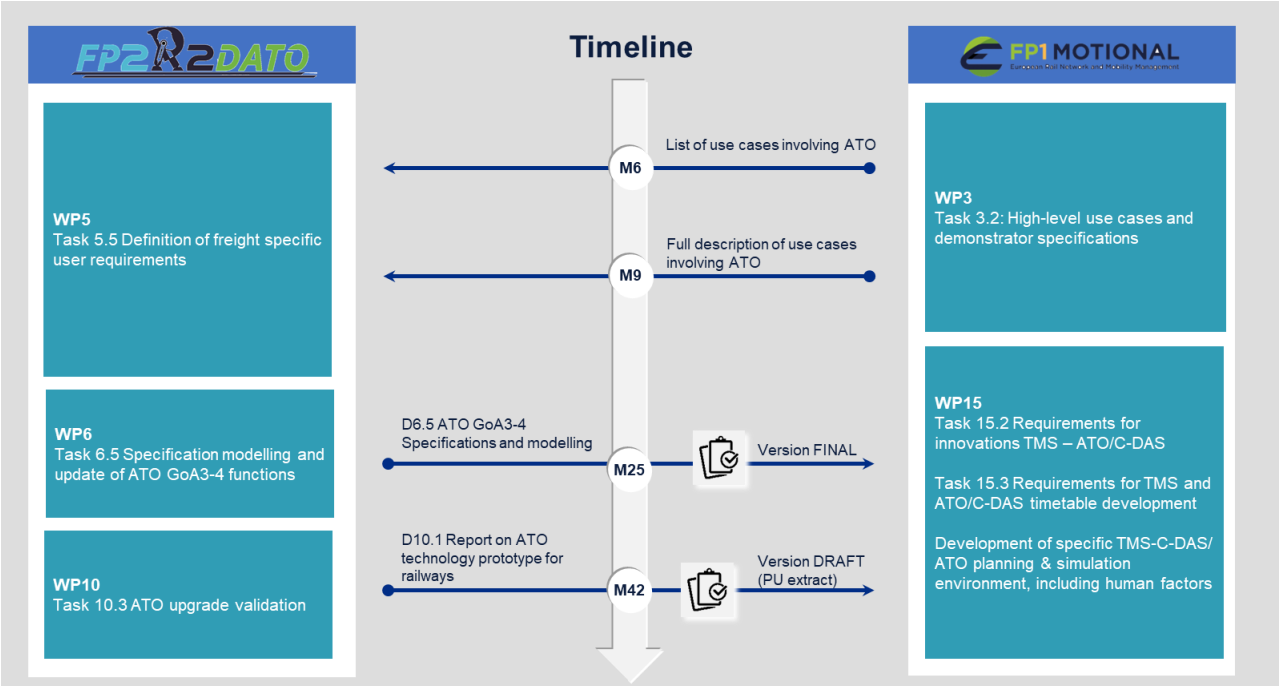

Figure 6: Exchanges with FP1

5.2 FP5 TRANSF4M-R

Figure 7 depicts the expected exchanges between the APC and FP5. While FP2 covers the automation of freight trains in mainline, FP5 is in charge of the automation in yards, either classified or hum yards.

This requires a proper coordination between the two projects and in particular between APC and FP5, as the technical enablers are in principle the same or adapted to the different operational conditions.

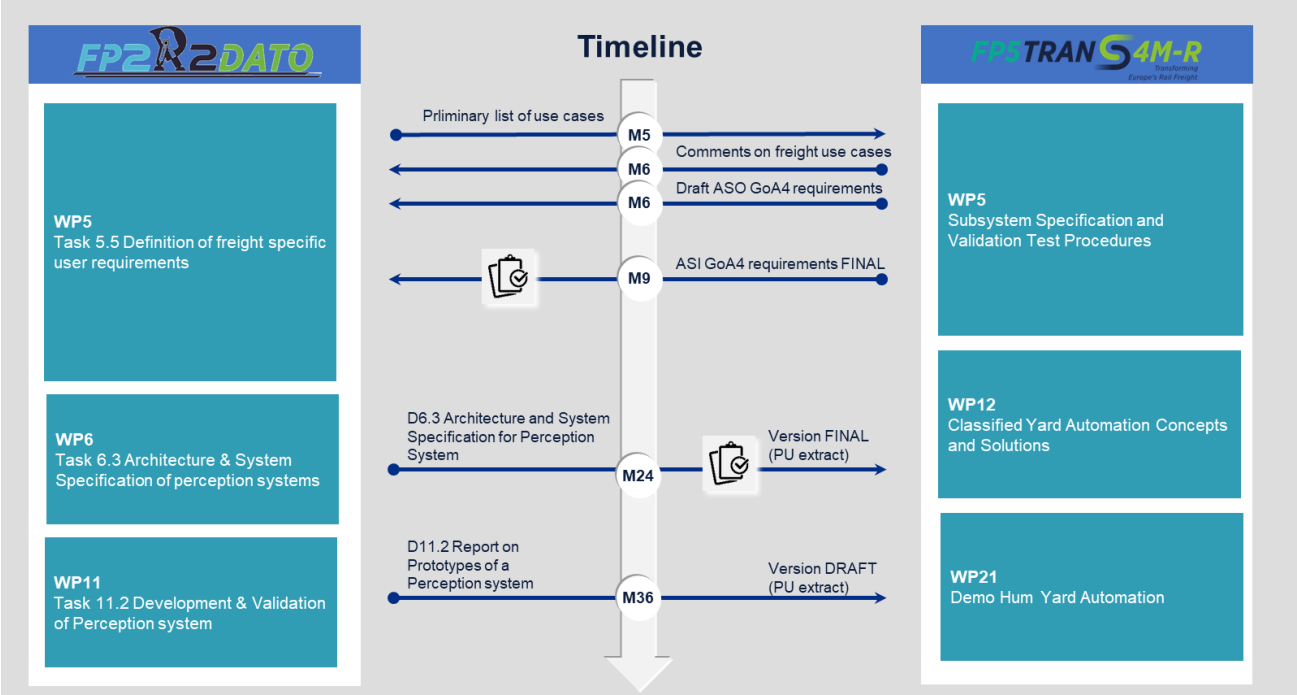

Figure 7: Exchanges with FP5

At least six major milestones are expected between the two projects.

1. **M5 (April 2023)**: FP2 WP5 provides a preliminary list of use cases that will be developed in 2023 and will feed the specification and later development of prototypes for demonstration.
2. **M6 (May 2023)**: FP5 WP5 will return comments on the use cases from the freight yard operation & DAC perspectives, complementing the expertise in Task 5.5.
3. **M6 (May 2023)**: FP5 WP5 will provide a first version of the ASO GoA4 requirements (mainly the ASO use cases) to let APC analyse the impact in the technical enablers and eventually integrate them in WP5.
4. **M9 (August 2023)**: FP5 WP5 delivers the final version of the ASO GoA4 requirements. This specification is intended to feed WP5 but also WP6 from M12 on.
5. **M24 (November 2024)**: as FP5 has declared its main interest in the perception technical enabler. Deliverable D6.3 on architecture and specification for the perception system will be shared with FP5 WP12. As this document is sensitive, a public extract will be provided.
6. **M36 (November 2025)**: although the development of the perception systems will last until the end of the project in May 2026 (M42) and will not be concluded in M36, a draft version of deliverable D11.2 reporting on the prototypes development for such systems would be shared with FP5, letting this project to evaluate the possibility of testing a prototype in the hump yard automation demonstrator. As with D6.3 this deliverable is sensitive, so a public extract will be shared.

A proper understanding of ATO and ASO commonalities and transition mechanisms is requiring regular meetings among both projects. Quarterly meetings are expected.

5.3 FP6 FUTURE

FP6 FUTURE, dealing with cost-efficient regional railways, also interacts with the APC on the ATO Technologies technical enabler mainly, as depicted in Figure 8.

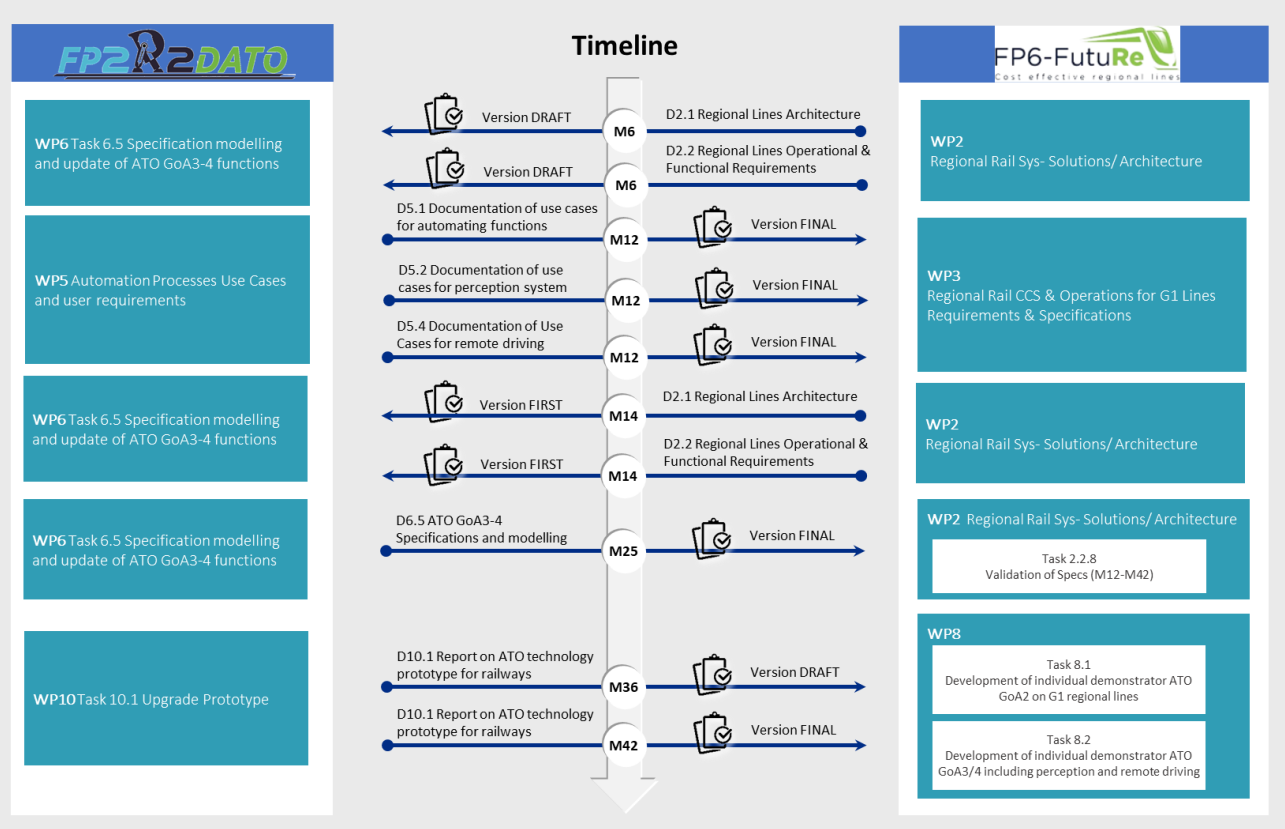

Figure 8: Exchanges with FP6

In this case five main milestones have been defined:

1. **M6 (May 2023)**: FP6 provides a draft version of the deliverable D2.2 containing the operational and functional requirements of regional lines for WP6 and D2.1 describing the architecture. Operational use cases are expected from FP6, to be integrated in WP5.
2. **M12 (November 2023)**: WP5 of FP2 R2DATO issues deliverables D5.1, D5.2 and D5.4 which are of high interest for deliverable D3.1 of FP6.
3. **M14 (January 2024)**: The final input of the deliverable D2.2 for FP2should then be ready and WP6 will be in charge of receiving it as an input for the specifications.
4. **M25 (November 2024)**: FP2 R2DATO will be delivering all specifications. In particular, deliverable D6.5 – ATO GoA3/4 Specifications and Modelling.
5. **M36 (November 2025)**: After issuing deliverable D6.5 WP10 of FP2 R2DATO will start the detailed design and implementation of the updated ATO prototypes which will feed the demonstrators (see 4.1) but will also be used in FP6. Therefore, a draft of deliverable D10.1 will be shared in M36 with WP8 of FP6.
6. **M42 (May 2026)**: FP6 WP8 will receive the final version of deliverable D10.1 letting that project continue its activities until its end in November 2026.

There is a strong link between FP2 R2DATO and FP6 FUTURE so regular exchanges are required in order to ensure a proper coordination among activities, including the Automation Processes Cluster. Quarterly meetings are envisaged to discuss common topics and exchanged deliverables.

5.4 SYSTEM PILLAR

Although the main high level interaction between FP2 R2DATO and the System Pillar is performed through WP3 as explained in chapter 4.2, it is also expected that several WPs of the Automation Process Cluster (APC) will be directly collaborating and exchanging with the System Pillar's domains, always under the management of the APC System Engineer. From FP2 R2DATO's side, the coordinator for the exchanges will be the APC Leader (Javier Goikoetxea), supported by the APC System Engineer (Bastian Simoni), and from the System Pilar the coordination for ATO will be done by Jens Nolte.

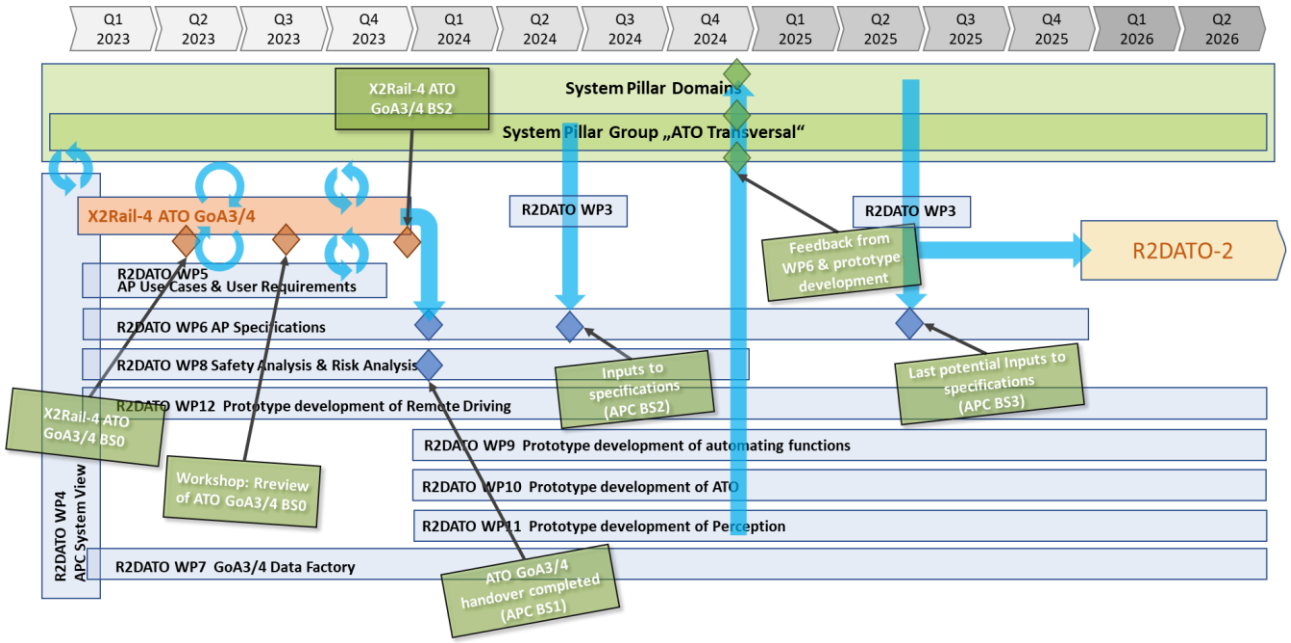

Figure 9: Exchanges with the System Pillar

The interaction between APC and System Pillar is complex and continuous, as can be seen in Figure 9. In this case, in addition, a new actor appears in the form of the X2Rail-4 project.

The starting point for the collaboration is the baselines 0 and 1 (BS0 & BS1) of the ATO GoA3/4 specification produced by X2Rail-4. A joint review will take place in Summer 2023 and will end with a workshop in M10 (September 2023).

As a consequence of the review process, it is expected that some open points already identified by the APC will be resolved:

- Definition of GoA3: what are the competencies of on-board staff? And therefore, which automatisms should be implemented?
- Scope of automated functions
- Functional concept of Remote Train Operation (RTO) as a vehicle function or as a control function.

- Adoption and common understanding of the architecture defined by X2Rail-4 as well as the collaboration steps and processes.

After the workshop, a transitional period of three months is expected until the completion of X2Rail-4 in M13 (December 2023). At that time the handover will be completed and only FP2 R2DATO and System Pillar will be in charge of maintaining the functional architecture. X2Rail-4 resulting architecture will be named as baseline 2 (BS2). This architecture will be further developed in WP6 and the System Pillar leading to the demonstrators. By that time, clear rules of operation and collaboration will have to be established, as well as defining who will own the model (in Capella) and the process for updating and approving changes.

In general, M18 (May 2024) is established as the latest time (freezing point) when changes introduced in the architecture by the System Pillar can be implemented in the demonstrators. At this point, APC baseline 2 (BS2) will be generated. For the sake of clarity, X2Rail-4 baselines and APC baselines are uncoupled.

Finally, a last revision cycle is envisaged at M30 (May 2025). Minor changes may still be integrated in the prototyping phase, but other major changes will have to be adopted and implemented in the successor project to R2DATO.

A relevant output from APC, mainly WP6, is the contribution to the Standardisation and TSI Input Plan (STIP), which is updated in annual basis. This process is performed through WP2 of FP2 R2DATO which consolidates the inputs received from all WPs (even beyond APC) as depicted in Figure 2.

The STIP represents a crucial guideline for all activities in the project, including the ones in APC, as the ultimate goal of FP2 R2DATO is to put innovations in the market, which only is possible if the solutions are standardised and included in the regulation.

FP2 R2DATO's WP4 will be in charge of updating the STIP from the APC side and monitor that the activities performed in WP6 and prototyping WPs follow the timing and produce the required inputs to accomplish the STIP.

5.5 Quality and Timely Delivery

All the projects mentioned in this chapter as well as R2DATO itself are subject to a contract that includes a clear description of the activities to be carried out as well as a planning, which must be respected. This inherently implies that there may be some misalignment in terms of scope and timing, not always fully resolved during the GAP phase.

Adjustments in the middle of the implementation of project work programmes can also sometimes be difficult to make and mitigation measures need to be put in place. The first, and most obvious, is to exchange partial results or documentation in early versions. The prioritisation of what and when to exchange should be mutually agreed by the project members concerned, so regular joint follow-up meetings are essential to identify conflict points and priorities. In the case of APC, it will be the T4.2 task that will carry out such follow-up and implement with the support of WP leaders and the FPM the necessary mitigations and corrections.

Certainly, in the first months of the project, WP5 of R2DATO has not had the expected input in the form of use cases (MS1 in M6) so the mitigation implemented was based on reusing the results of previous projects such as TAURO or X2Rail-4 to the maximum and on assumptions, perfectly identified in the WP5 deliverables.

The case of WP6 will be similar. The inputs concerning the specification and the architecture would be required by M12, otherwise they would not be integrated in the ongoing work and later demonstrated in the project but in next waves of the Flagship Area 2. Nevertheless, WP6 will count on a closer and regular collaboration with the System Pillar to support any decision making in terms of assumptions and priorities.

6 CONCLUSIONS

This document describes the planned interactions between the Automation Processes Cluster (APC), which are internal to FP2 R2DATO but also external to the other flagship projects and the System Pillar. The importance of the Shift2Rail projects, especially TAURO and X2Rail-4, in APC is also noteworthy. For the latter project, specific collaborative actions have been established as it will not be completed until December 2023.

In general, Europe's Rail flagship projects have had a slow start due to the complexity of the set-up and the scale of the projects. This has been compounded by the emergence of a new player such as the System Pillar. All this has meant that the elaboration of this deliverable has been laborious and has required more time and effort than initially foreseen. It would have been preferable to have been able to advance in the definition of interfaces and collaboration processes prior to the start of operations, during the GAP phase.

It should also be noted that what is described in this document is a snapshot at the date of submission and that over the life of the project these interrelationships may change. However, deliverable D4.1 represents an excellent starting point to establish a clear picture of each other's needs as well as a timeframe for the main exchanges and milestones.

The information contained in the document reflects the conclusions drawn from bilateral inter-cluster and inter-project meetings and is subject to interpretation by APC members. In addition, this deliverable D4.1 is part of the maturity checkpoint #1 (MCP#1), so the participation of the other stakeholders has validated the content of the deliverable through the common understanding of the various interactions.

REFERENCES

[1] X2Rail-4 website: https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-4

[2] TAURO website: https://projects.shift2rail.org/s2r_ipx_n.aspx?p=tauro

[3] ARCC website: https://projects.shift2rail.org/s2r_ip5_n.aspx?p=ARCC

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[6] FP5 TRANS4M-R website: https://projects.rail-research.europa.eu/eurail-fp5/

[7] FP6 FUTURE website: https://projects.rail-research.europa.eu/eurail-fp6/

[8] System Pillar website: https://rail-research.europa.eu/system_pillar/