Rail to Digital automated up to autonomous train operation

D42.3 – Testing reports & assessment

Approach to demonstration for autonomous movements in controlled areas.

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1 EXECUTIVE SUMMARY

This deliverable presents the testing reports and assessment of the WP42 autonomous movement demonstrator developed within the FP2-R2DATO project. The work focuses on the demonstration of autonomous tram movements in controlled depot areas, using the SL18 tram-lab units retrofitted for autonomous movement and tested at Holtet depot, Oslo.

The objective of WP42 was to move beyond isolated functional validation and demonstrate that autonomous depot movements can be executed in a real operational environment under controlled conditions. The demonstrator covered mission preparation, autonomous movement execution, speed regulation, obstacle detection and response, communication degradation management, supervision, and integration with the existing vehicle architecture.

The testing approach followed the methodology already applied in WP41 for remote driving and telecommands, including structured test descriptions, test reports, configuration control, independent test execution, validation records and feedback to risk assessments. Several test campaigns were carried out at Holtet depot between April and June 2026, progressing from initial autonomous movement validation to extended robustness testing and final end-to-end demonstration.

The results confirm that the defined autonomous movement test cases were successfully completed in the demonstrator environment. The validation was achieved through an iterative process, where issues identified during early testing were analysed, corrected and re-tested until the expected behaviour was confirmed. This is a relevant result for a European research and innovation project: the demonstrator did not only execute predefined functions but also provided evidence of a realistic engineering validation cycle in an operational depot environment.

The KPI assessment complements the functional test results by evaluating the technical performance, operational relevance and scalability potential of the solution. The assessment indicates that autonomous depot movements can provide a credible basis for future automation of depot workflows, including vehicle repositioning, preparation movements, supervision-assisted manoeuvres and reduced dependency on manual intervention in controlled areas. At the same time, the deliverable clearly distinguishes between demonstrator maturity and commercial product readiness. Some operational KPIs, especially those related to productivity gains, reaction time reduction and full scalability, require further quantitative consolidation against agreed operational baselines.

Overall, WP42 demonstrates that autonomous tram movements in controlled depot areas are technically feasible and operationally relevant. The project has produced a valuable demonstrator-level validation, while identifying the additional steps required for industrialisation, including extended validation, safety case development, operational procedure alignment, cybersecurity considerations, maintainability assessment and integration into future depot automation strategies.

TABLE OF CONTENTS

Report Contributors **2**
1 Executive Summary **3**
Table of Contents **4**
List of Figures **5**
2 INTRODUCTION **6**
2.1 Context and Objectives 6
2.2 Document structure 6
3 AUTONOMOUS MOVEMENT DEMONSTRATION **7**
3.1 Testing strategy and test cases 7
3.1.1 Testing methodology 7
3.1.2 Testing scenario 8
3.1.3 Test cases specification 8
3.2 Test results 12
3.2.1 Testing results methodology 12
3.2.2 Testing report 12
3.3 KPIs 15
3.3.1 KPI Assessment Framework 15
3.3.2 KPIs for Autonomous Depot Movements 15
3.3.3 KPI Measurement Methodology 17
3.3.4 KPI Results and Assessment 18
3.3.5 KPI Impact conclusions 22
4 CONCLUSIONS **24**
References **25**
ANNEX 1: Example of completed ALIVE Testing Description **26**
ANNEX 2: Example of completed ALIVE Testing PROCEDURE and test REPORT **27**

LIST OF FIGURES

Figure 1: Testing tracks at Holtet depot. 8
Figure 2: Pedestrian dummy placed on the track at Holtet depot. 8
Figure 3: Test Description Block1 example. 11
Figure 4: Test Description Block2 example. 14

2 INTRODUCTION

2.1 CONTEXT AND OBJECTIVES

WP42 focuses on the demonstration and assessment of autonomous tram movements in controlled depot areas. Within the FP2-R2DATO project, the objective of this deliverable is to consolidate the testing reports, validation evidence and KPI assessment related to the autonomous movement demonstrator implemented on the SL18 tram-lab units and tested at Holtet depot in Oslo.

The deliverable builds on the previous work performed in D42.1, where the test cases and validation criteria were defined, and D42.2, where the approach to the autonomous movement demonstration was described. D42.3 therefore provides the final testing and assessment view, covering the test strategy, test campaigns, obtained results, KPI evaluation, limitations and lessons learned.

The scope of the assessment is demonstrator-level validation. The results are intended to confirm the technical feasibility and operational relevance of autonomous tram movements in a controlled depot environment, while clearly distinguishing this achievement from full commercial deployment readiness.

2.2 DOCUMENT STRUCTURE

The deliverable D42.3 is structured as follows:

- Chapter 1 provides the executive summary of the deliverable.
- Chapter 2 introduces the context, objectives and structure of the document.
- Chapter 3 presents the autonomous movement demonstration, including the testing strategy, test environment, test cases, test results and KPI assessment.
- Chapter 4 summarises the main conclusions, limitations, lessons learned and recommendations for future development.

3 AUTONOMOUS MOVEMENT DEMONSTRATION

This chapter consolidates the WP42 autonomous movement demonstration activities performed at Holtet depot. It presents the testing strategy, the operational test environment, the integration and functional test cases, the test campaign results and the KPI assessment. The chapter is structured to show both the final conformity of the demonstrator against the defined test cases and the progressive validation process followed to reach this result.

3.1 TESTING STRATEGY AND TEST CASES

This section describes the testing strategy applied to the autonomous movement demonstrator, including progressive validation, the test environment, roles, safety arrangements and the structure of the test cases.

The strategy was based on progressive validation, starting from integration and configuration checks and moving towards functional autonomous movement tests under controlled depot conditions.

3.1.1 Testing methodology

This subsection describes the testing methodology, including preparation, configuration management, safety arrangements, execution steps, reporting rules, and filing process.

The methodology applied in WP42 is based on the testing strategy previously implemented in WP41 for the Remote Driving and Telecommands demonstrator. Given the satisfactory outcomes achieved during WP41, it was decided to adopt the same approach for WP42.

In summary, a collaborative framework between CAF and Sporveien Trikken has been established. This framework defines the methodology for conducting all required tests related to the autonomous movements demonstrator.

Within this framework, the roles involved in test execution, the testing documentation templates and the different steps of the testing process are clearly defined. The full methodological framework is described in Section 2.1.1 “Testing Methodology” of deliverable *D41.2 – Testing Reports & Assessment*. In D42.3, the same framework is applied to autonomous movement testing, including test preparation, configuration control, safety arrangements, test execution records, deviation management, reporting rules and evidence filing.

To ensure full coverage of the defined test cases, several testing campaigns were planned and executed throughout the project.

3.1.2 Testing scenario

All dynamic tests were carried out at Holtet depot. This location provided a representative controlled environment for validating autonomous depot movements while maintaining operational supervision and safe test execution conditions.

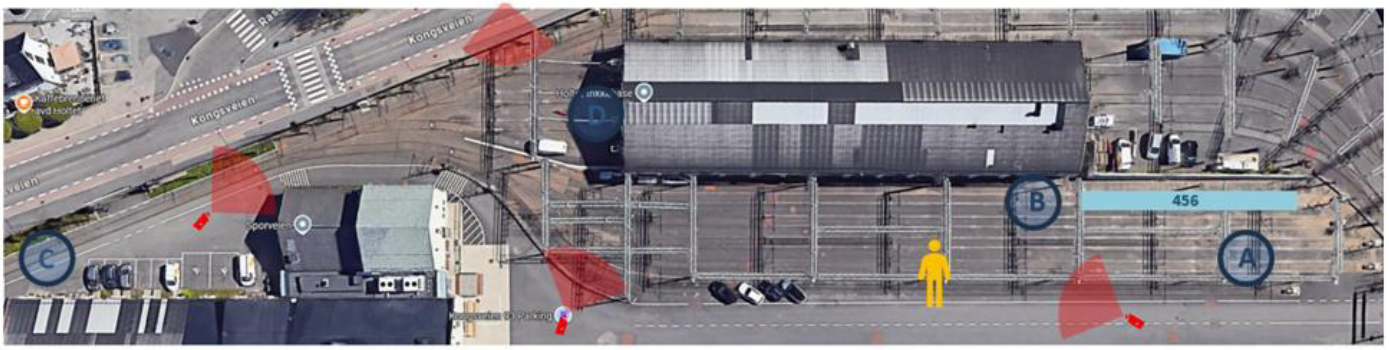


Figure 1: Testing tracks at Holtet depot.

- The CERES station used to configure and execute missions was installed in a control room with direct visibility of the track.
- Two units (455 and 456), already retrofitted for autonomous movement, were used during the tests.
- Several locations within the depot were defined as start and end points (A, B, C, and D) to configure autonomous mission routes.
- A pedestrian dummy was placed on the track to validate the obstacle detection system.



Figure 2: Pedestrian dummy placed on the track at Holtet depot.

3.1.3 Test cases specification

This subsection presents and describes the test cases selected for the autonomous movement demonstrator.

As introduced in Deliverable D42.1, the validation activities are structured into two main scenarios:

- Integration validation, covering the assessment of newly installed equipment and ensuring non-regression of existing functionalities.
- Functional validation, focused on verifying the performance of the newly integrated functions.

3.1.3.1 Integration test

The purpose of the integration test is to validate the integration of the modifications implemented on the vehicle and to verify that they do not have a negative impact on previously tested vehicle functions or subsystems. The test also verifies the correct operation and functionality of the relevant electrical circuits.

To check the correct integration of the new systems, the *Auxiliary Circuit Test* that was defined for WP41 "Remote driving of tramways demonstrator" has been updated to include the new equipment.

The following test cases are covered in this test procedure:

- Verification of driver's safety device in mode 0 – all installation for perception and remote control are switched off.
- Verification of driver's safety device in mode 1 – only installation for perception is switched on.
- Verification of driver's safety device in mode 2 – all installation for perception, remote control and autonomous movements are switched on.
- Tram off - Remote wake up test.
- Remote control commands test.
- Remote driving loop test.
- Remote active cabin test.
- Remote driving commands test.
- MCB monitoring
- TPS (LOZ+V2X+ATO+IPM) encoders, GNSS and TRDP test

Note: Three different operational modes have been defined for the demonstrator unit.

- Mode 0: The unit operates without any modifications to the approved baseline configuration.
- Mode 1: The perception systems are activated while retaining the train control from Mode 0. In this mode, the unit is not equipped with any systems capable of taking actions on the vehicle.
- Mode 2: A new train control system is activated, enabling the execution of actions on the vehicle.

3.1.3.2 Functional test

The purpose of these tests is to verify the correct operation and functionality of the autonomous movements.

The following test cases have been defined to validate the new functionality:

Test case	Test objective	Input data	Preconditions	Expected result	Result
TC-AUTO-001	Mission profile generation and validation	Route configuration in CERES: - initial and target point - operational speed	Tram ready to enter in autonomous mode: - switched on - no active cab (key)	Mission accepted and ready for execution	OK
TC-AUTO-002	Autonomous movement from parking to target point	Route configuration in CERES: - initial and target point: from A to B - operational speed	Tram located in point A	Vehicle completes mission within defined constraints	OK
TC-AUTO-003	Speed regulation during autonomous movement	Route configuration in CERES: - initial and target point: from A to B - operational speed	Tram located in point A	Vehicle respects speed profile and depot limits	OK
TC-AUTO-004	Obstacle detection and safe response	Different obstacles located in the track: - A pedestrian dummy in the track - A tram parked in the track	Obstacles located in the mission track	Obstacle detected and expected response triggered	OK
TC-AUTO-005	Communication degradation management	Force a communication error: - Disconnect CERES ethernet connection	Tram and CERES ready to execute a mission.	System reacts according to safety concept	OK

Note: The "OK" result corresponds to the final validated status of each test case after completion of the applicable testing and re-testing activities.

All these test cases are covered in the Test Descriptions prepared for each testing campaign:

- ALIVE_TD_CAF_0017 – TPS functionalities / autonomous movements
- ALIVE_TD_CAF_0028 – TPS functionalities / autonomous movements 2.0

ALIVE_TD_CAF_0035_- TPS functionalities final tests / autonomous movementsIn addition to the main testing campaigns, dedicated test sessions have been scheduled to investigate and resolve specific issues. Dedicated Test Description was defined for each testing session:

- ALIVE_TD_CAF_0013 - CERES SW update
- ALIVE_TD_CAF_0015 - OTIV SW update & pre-validations
- ALIVE_TD_CAF_0019 - TPS-OTIV comms tests
- ALIVE_TD_CAF_0024 - CERES troubleshooting
- ALIVE_TD_CAF_0026 - TPS-CERES test: mission execution
- ALIVE_TD_CAF_0027 - PER testing - OTIV

As described in Section *3.1.1 "Testing Methodology"*, Block 1 of the *ALIVE Testing Description Template* was completed before each testing session in order to define the test procedure.



1. BLOCK 1

1. **Title**	TPS functionalities tests
2. **Technical Leader**	Josune Aranburu
3. **Test Type**	Type 2.2
4. **Subsystems involved**	TPS, CERES, TCMS subsystems, OTIV
5. **Description of the Test**	The objective of the test is: - Validate the location enhancement with RTK (new antenna installation) - Perform autonomous movements without perception or speed supervision modules - Validate OTIV and TPS communication protocol and object recording - Validate the correct communication protocol between TPS and Ceres - Perform autonomous movements with speed restrictions from Ceres - Validate the identification of objects on tracks
6. **Units**	SL18-455 or/and 456
7. **STR Roles**	Test team leader in Oslo, remote driver, on-board driver.
8. **CAF Roles**	Technical Leader, CAF engineers, remote driver

Figure 3: Test Description Block1 example.

Note: A complete Test Description example is provided in Annex 1. The first test campaign test procedure (ALIVE_TD_CAF_0017 – TPS functionalities / autonomous movements) is included.

3.2 TEST RESULTS

This section consolidates the results obtained during the WP42 autonomous movement test campaigns, including conformity assessment and deviations.

3.2.1 Testing results methodology

The tests have been executed and validated by testing engineers who are independent of the project development team, ensuring objectivity in the assessment.

For **integration tests**, a test report is generated and stored in the CAF database. Each report includes a completed test results template containing the following information:

- Vehicle unit
- Test date
- Test location
- Environmental conditions
- Software versions
- Results for each test case
- Comments
- Personnel involved in the test, along with their validation signatures

For **functional tests**, and following the testing procedure framework explained in Section 3.1.1 *"Testing Methodology"*, Block 2 of the *ALIVE Testing Description Template* is completed after each testing campaign.

Test reports are generated, stored in the CAF database, and shared with its partner SPV. Each report includes a completed test results template containing the following information:

- Updates to the initial information provided in Block 1
- A brief description of the results obtained
- Configuration of the units after test execution (including software versions)
- Lessons learned, where applicable, for future test procedures
- Actions derived from the test for both partners
- Feedback to risk assessments

3.2.2 Testing report

This subsection includes or references the final test reports generated during the WP42 autonomous movement campaigns.

Test campaign	Location	Date	Vehicle unit	Scope	Overall status	Evidence reference

Holtet testing campaign 1	Holtet depot, Oslo	21-27 April 2026	UT455	Initial autonomous movement validation	Completed - Improvement actions identified	TD_CAF_0017_3
Holtet testing campaign 2	Holtet depot, Oslo	25-29 May 2026	UT455	Extended use cases and robustness validation	Completed	TD_CAF_0028_3
Final demonstrator campaign	Holtet depot, Oslo	16-19 June 2026	UT455	End-to-end autonomous depot movement demonstration	Completed	TD_CAF_0035_3

All defined test cases were completed with a final “OK” result. This final status was achieved through an iterative validation process, where deviations or improvement needs identified during early testing were analysed, corrected and re-tested in subsequent sessions. The final outcome therefore reflects both the conformity of the demonstrator against the defined test cases and the effectiveness of the engineering validation cycle applied during WP42.

After each testing campaign or session, Block 2 of the ALIVE Testing Description Template was completed to document the results and track the progress made during each iteration.



CAF	CAF TESTS RECORD	sporveien
CAF.VH.P18.MD.002-GN	TPS functionalities tests / autonomous movements	
Anterior: CAF.VH.P15.MD.085-GN A	SL18 R2DATO // ALIVE	

BLOCK 2

1. Updated info in Block 1	N/A
2. Description of the results (summary)	Tests summary: 1. **RTK Positioning Validation** RTK functionality was successfully validated in all tested scenarios, including cold startup conditions. RTK corrections were correctly applied, resulting in accurate and stable localization of the TPS throughout the tests. 2. **Autonomous Movements in Depot (without perception/speed supervision)** Most planned autonomous missions were executed successfully across the different depot paths and cab change scenarios. However, not all missions could be fully validated. Issues were identified in the algorithm parametrization, affecting smoothness and consistency of tram movements. Dynamic behaviour requires further tuning to ensure homogeneous performance across different conditions, particularly on **flat, uphill, and downhill sections**. 3. **PER Validation – OTIV and TPS Communication** The communication protocol between OTIV and TPS was validated, and multiple static and dynamic object detection tests were performed. While the protocol itself functioned correctly, several issues were identified:

Figure 4: Test Description Block2 example.

Note: A complete Test Description and test report example is provided in Annex 2. The final test campaign test procedure (ALIVE_TD_CAF_0035_- TPS functionalities final tests / autonomous movements) is included where the final test results can be checked,

3.3 KPIs

The objective of this section is to assess the expected impact of the autonomous depot movement demonstrator developed under WP42 by means of Key Performance Indicators. While Sections 3.1 and 3.2 focus on the functional validation of the implemented solution through test cases and test reports, this section provides an additional assessment layer focused on the operational value, technical maturity and potential scalability of autonomous tram movements within depot environments.

The KPI assessment follows the same general rationale applied in previous R2DATO demonstrator deliverables, where the evaluation was structured not only around technical conformity but also around the operational impact of the implemented functions. For D42.3, the focus is shifted from remote driving and telecommand to autonomous movement in controlled depot areas. The assessment therefore concentrates on the capability of the vehicle to execute predefined autonomous missions, regulate speed, interact with the depot operational environment, detect obstacles and support more efficient depot workflows.

The KPI assessment presented in this section consolidates the evidence available from the WP42 test campaigns. The assessment distinguishes between confirmed demonstrator results, qualitative operational assessment and quantitative indicators that require further baseline consolidation. Where no predefined quantitative target was available for the demonstrator, results are assessed against the applicable test-case acceptance criteria and are explicitly identified as qualitative or pending quantitative consolidation. This distinction ensures that the conclusions remain balanced: the demonstrator has validated the core autonomous movement functions in a real depot environment, while some operational impact indicators still require additional data before being translated into definitive productivity or efficiency figures.

3.3.1 KPI Assessment Framework

The KPI assessment is based on three complementary perspectives:

- Functional and technical performance, assessing whether the autonomous movement functions are executed correctly, safely and consistently.
- Operational impact, assessing whether autonomous movements may reduce reaction time, improve depot workflow efficiency and support future scalability.
- Integration and deployment maturity, assessing whether the solution can coexist with the existing SL18 vehicle architecture and depot operational procedures without negative impact.

3.3.2 KPIs for Autonomous Depot Movements

KPI	Type	Explanation	Measurement criteria	Evaluator
Autonomous mission execution success rate	Technical / Functional	Percentage of autonomous mission profiles successfully executed from mission request	% of missions completed successfully	CAF / STR

		to mission completion.		
System integration without impact on existing vehicle	Technical / Integration	Integration without negative impact on the homologated baseline vehicle configuration.	Yes / No	STR / CAF
Speed regulation performance	Technical / Safety-related	Vehicle compliance with target speed profile and depot speed limits during autonomous movement.	Deviation from target speed; exceedance events	CAF
Obstacle detection and response performance	Technical / Safety-related	Detection of relevant obstacles and triggering of the expected autonomous response.	Detection rate; response correctness; false positives / false negatives	CAF / STR
Communication and supervision availability	Technical	Availability of the communication and supervision chain required to command, monitor and supervise autonomous missions.	Availability %; number of communication interruptions	CAF
Reaction time reduction for depot movements	Operational	Reduction in time required to initiate and execute selected depot manoeuvres versus conventional processes.	% reduction versus baseline	STR
Productivity impact on depot operations	Operational	Potential impact on shunting, parking,	Qualitative assessment	STR

		workshop access and vehicle preparation workflows.	and/or % improvement	
Operational usability for depot staff	User / Operational experience	Clarity, usability and operational acceptability of the autonomous movement process.	Rating 1–5 and qualitative feedback	STR
Scalability potential	Strategic / Deployment	Potential scalability to additional vehicles, depot tracks or operational scenarios.	Qualitative assessment	CAF / STR

3.3.3 KPI Measurement Methodology

The KPI assessment is performed using the evidence collected during the WP42 test campaigns and the corresponding records referenced in Section 3.2 and the annexes. The relevant sources include:

- Test case execution records.
- Test reports generated during Holtet depot testing campaigns.
- Vehicle logs and onboard system data.
- CERES or ground supervision logs, where applicable.
- Perception system logs.
- Communication system logs.
- Operator observations and structured feedback.
- Comparison with baseline manual or remote-supervised depot procedures, where available.

The following measurement principles shall be applied:

1. No KPI shall be evaluated only by perception or opinion if objective evidence is available.
2. Operational KPIs shall be assessed against a defined baseline agreed with the operator.
3. Qualitative KPIs shall be explicitly attributed to the evaluator.
4. Incomplete KPIs shall remain marked as pending rather than estimated without evidence.
5. The assessment shall distinguish between demonstrator maturity and product maturity.

3.3.4 KPI Results and Assessment

The following tables summarise the KPI assessment based on the available WP42 test evidence. Where quantitative values are not yet available or require an agreed operational baseline, the result is expressed as a qualitative demonstrator-level assessment rather than as a numerical claim.

1. **Autonomous mission execution success rate**

This KPI measures the ability of the autonomous movement system to execute complete depot mission profiles. A mission is considered successful when the vehicle receives the mission command, validates the necessary preconditions, executes the required movement, respects the applicable constraints and reaches the intended final state without requiring unplanned manual intervention.

Definition	Measurement	Result	Status
Percentage of autonomous missions completed successfully	%	Final OK status for defined test cases	Demonstrated at test case level
Number of missions requiring unplanned manual intervention	Number	No unplanned manual intervention reported in final validated test status	To be confirmed against final test logs
Number of missions aborted due to system or operational constraints	Number	No aborted mission reported in final validated test status	To be confirmed against final test logs

2. **System integration without impact on existing vehicle**

This KPI assesses whether the autonomous movement solution has been integrated into the SL18 tram-lab architecture without creating negative impact on the existing vehicle configuration.

Definition	Measurement	Result	Status
Mechanical and electrical integration is clearly identified, maintainable and segregated from baseline systems	Yes / No	Yes — based on integration test execution	Confirmed at demonstrator level
Operational modes remain clearly differentiated between homologated operation, data acquisition and autonomous testing	Yes / No	Yes — based on integration test execution	Confirmed at demonstrator level

No regression detected on baseline vehicle operation due to autonomous movement equipment	Yes / No	Yes — based on integration test execution	Confirmed at demonstrator level

3. Speed regulation performance

This KPI evaluates the capability of the autonomous movement system to regulate vehicle speed according to mission requirements, depot operational constraints and applicable safety limits.

Definition	Measurement	Result	Status
Maximum speed exceedance events during autonomous missions	Number	No exceedance reported in final validated test status	To be confirmed against logs
Average deviation from target speed profile	km/h or %	Requires quantitative log analysis	Pending quantitative consolidation
Correct stop at predefined mission endpoint	Yes / No / %	OK in defined test cases	Demonstrated at test case level
Correct speed adaptation to operational constraints	Yes / No / %	OK in defined test cases	Demonstrated at test case level

4. Obstacle detection and response performance

This KPI assesses the ability of the autonomous movement system to detect relevant obstacles within the movement envelope and trigger the expected response.

Definition	Measurement	Result	Status
Obstacle detection rate in defined test scenarios	%	Obstacle detected in defined test scenarios	Demonstrated at test case level
Correct autonomous response after obstacle detection	%	Expected response triggered in defined test scenarios	Demonstrated at test case level
False positive events affecting mission execution	Number	Not reported in final validated test status	To be confirmed against perception logs

False negative events detected during test review	Number	Not reported in final validated test status	To be confirmed against perception logs
Emergency or safety stop triggered when expected	Yes / No / %	OK in defined obstacle scenarios	Demonstrated at test case level

5. Communication and supervision availability

This KPI measures the availability and robustness of the communication and supervision chain used to command and monitor autonomous depot movements.

Definition	Measurement	Result	Status
Communication availability during autonomous test missions	%	Requires communication log consolidation	Pending quantitative consolidation
Number of communication interruptions affecting mission execution	Number	Requires communication log consolidation	Pending quantitative consolidation
Number of supervision data losses affecting operator awareness	Number	Requires communication log consolidation	Pending quantitative consolidation
Correct safe reaction in case of communication degradation	Yes / No	OK in defined communication degradation test	Demonstrated at test case level

6. Reaction time reduction for depot movements

This KPI evaluates the reduction in time needed to perform selected depot operations through autonomous movement capabilities. For the demonstrator, timing is considered in seconds or tens of seconds depending on the manoeuvre. The manual baseline and the autonomous reference shall be derived from comparable executions of the same operation under equivalent conditions; until such a consistent operator baseline is available, no numerical reduction or pass/fail threshold is claimed.

Operation	Baseline time	Autonomous movement time	Reduction	Status
Parking position to workshop access	TBD	TBD	Requires agreed operational baseline	Pending operational baseline

Workshop area to parking position	TBD	TBD	Requires agreed operational baseline	Pending operational baseline
Repositioning between depot tracks	TBD	TBD	Requires agreed operational baseline	Pending operational baseline
Preparation movement before operation	TBD	TBD	Requires agreed operational baseline	Pending operational baseline
Parking after operation	TBD	TBD	Requires agreed operational baseline	Pending operational baseline

7. Productivity impact on depot operations

This KPI evaluates the extent to which autonomous movements could improve depot productivity by reducing manual intervention, improving vehicle availability, accelerating vehicle preparation and enabling more flexible sequencing of depot tasks.

Definition	Measurement	Result	Status
Productivity impact on shunting operations	% or qualitative	Qualitative potential identified	Requires further operational validation
Productivity impact on vehicle preparation	% or qualitative	Qualitative potential identified	Requires further operational validation
Productivity impact on parking after operation	% or qualitative	Qualitative potential identified	Requires further operational validation
Potential reduction of staff exposure in operational movement areas	Qualitative	Qualitative potential identified	Requires further operational validation

8. Operational usability for depot staff

This KPI captures feedback from operational personnel involved in test preparation, supervision or execution. The 1–5 scale is interpreted consistently across the criteria: 1 indicates a very low or unfavourable assessment and 5 a very high or favourable assessment. The rating remains a qualitative demonstrator-level input and is complemented by the evaluator's comments.

Definition	Measurement	Result	Status
Clarity of mission preparation process	Rating 1–5	Qualitative feedback from test execution	To be consolidated with STR feedback
Clarity of supervision information	Rating 1–5	Qualitative feedback from test execution	To be consolidated with STR feedback

Perceived compatibility with depot procedures	Rating 1–5	Qualitative feedback from test execution	To be consolidated with STR feedback
Overall operational acceptability	Rating 1–5	Qualitative feedback from test execution	To be consolidated with STR feedback

9. Scalability potential

This KPI assesses whether the autonomous movement concept demonstrated in WP42 could be scaled beyond the prototype test configuration.

Definition	Measurement	Result	Status
Applicability to additional SL18 units	Qualitative	Positive at demonstrator concept level	Further industrialisation required
Applicability to additional depot routes or tracks	Qualitative	Positive at demonstrator concept level	Further industrialisation required
Dependency on depot-specific infrastructure	Qualitative	Positive at demonstrator concept level	Further industrialisation required
Reusability of architecture for future commercial implementation	Qualitative	Positive at demonstrator concept level	Further industrialisation required

3.3.5 KPI Impact conclusions

The KPI assessment supports demonstrator-level validation of autonomous depot movements within the scope and acceptance criteria of the defined test cases. The principal supporting evidence is provided by the test campaign records summarised in Section 3.2 and the completed examples included in Annexes 1 and 2. The strongest evidence relates to the technical and functional KPIs, including mission execution, system integration, speed regulation, obstacle response and supervised operation in controlled depot conditions; Operational indicators for which no agreed baseline was established within the scope of WP42 are retained as qualitative demonstrator-level assessments; their further definition and consolidation may be addressed as part of Wave 2 activities aimed at completing the validation of autonomous operations in controlled areas.

Operational KPIs indicate relevant potential for future depot automation, particularly for vehicle preparation, parking, repositioning and reduction of manual intervention in controlled movement areas. However, these KPIs shall be interpreted as potential impact indicators unless supported by an agreed operational baseline and consolidated timing data.

The scalability assessment is positive at concept level. The demonstrated architecture provides a credible basis for future extension to additional vehicles, depot routes or depot automation scenarios. Nevertheless, transition towards industrial or commercial deployment would require further

validation, safety case consolidation, cybersecurity assessment, maintainability evaluation and integration with operator procedures.

4 CONCLUSIONS

The WP42 testing activities have successfully demonstrated autonomous tram movements in a controlled depot environment. The tests carried out at Holtet depot validated the main functional capabilities required for the demonstrator, including mission generation and validation, autonomous movement execution, speed regulation, obstacle detection and response, supervision, communication degradation management and integration with the SL18 tram-lab architecture.

A key conclusion of the work is that autonomous depot movement is no longer only a conceptual use case, but a technically demonstrable capability under controlled operational conditions. The demonstrator has shown that a tram can receive a predefined mission, execute an autonomous movement within depot constraints, react to relevant operational events and remain integrated with the existing vehicle architecture without compromising the baseline operational modes defined for the test vehicle.

The validation process also confirmed the importance of an iterative testing approach. Not all expected results were obtained at the first attempt; however, the structured testing methodology allowed issues to be identified, corrected and re-tested across successive campaigns. This iterative process is considered a positive outcome of the project, as it reflects the realistic maturation path required for complex autonomous railway systems.

From a KPI perspective, the results support a positive assessment of the demonstrator maturity. The strongest evidence relates to functional execution, system integration, speed control, obstacle response and supervised autonomous operation in a representative depot environment. The operational impact KPIs also indicate relevant potential for future depot automation, particularly in relation to vehicle preparation, parking, repositioning and reduction of manual intervention in controlled movement areas. However, the quantification of productivity gains and reaction time reduction requires additional baseline data and longer operational observation.

The demonstrator should therefore be interpreted as a significant step towards autonomous urban rail operations, but not yet as a full commercial deployment validation. Further work is required to progress from demonstrator maturity to product maturity, including extended test coverage, safety case consolidation, cybersecurity assessment, operational procedure definition, maintainability analysis, fleet-level scalability studies and integration with depot management processes.

In conclusion, WP42 has delivered a credible and relevant European demonstrator for autonomous tram movements in depot. The work provides evidence that autonomous functions can be integrated, tested and assessed in a real depot environment, while also defining the technical and operational pathway required for future deployment. The results constitute a strong foundation for subsequent developments in autonomous urban rail mobility and depot automation.

REFERENCES

- D42.1 – Collection of test cases and validation criteria
- D42.2 – Autonomous movements of trams in depot. Approach to demonstration for autonomous movements in controlled areas.
- D41.2 – Testing reports & assessment. Results of the remote driving of tramways demonstrator.
- FP2-WP42-D-CAF-007-01 – Deliverable Development Plan for D42.3 – Testing reports & assessment.

ANNEX 1: EXAMPLE OF COMPLETED ALIVE TESTING DESCRIPTION

ANNEX 2: EXAMPLE OF COMPLETED ALIVE TESTING PROCEDURE AND TEST REPORT

Code	TD_CAF_0017_3
Vehicle / Contract	SL18 R2DATO // ALIVE
Concept	ALIVE Testing Description

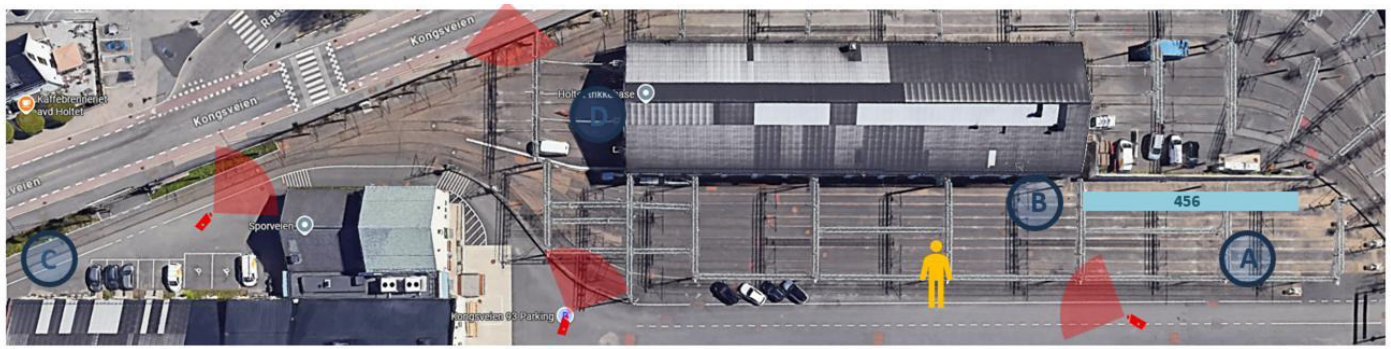
EDITION CONTROL

EDITION	REASON	DATE
-	First issue	11/02/2026
A	Tests speed specification detailed	24/03/2026
B	Block 2 updated	29/04/2026

Prepared by:	Reviewed by:
Name: Nacho Celaya Date: 27/10/2023	Name: Dusan Patrik Klago Date: 27/10/2023

1. BLOCK 1

1. Title	TPS functionalities tests
2. Technical Leader	Josune Aranburu
3. Test Type	Type 2.2
4. Subsystems involved	TPS, CERES, TCMS subsystems, OTIV
5. Description of the Test	The objective of the test is: - Validate the location enhancement with RTK (new antenna installation) - Perform autonomous movements without perception or speed supervision modules - Validate OTIV and TPS communication protocol and object recording - Validate the correct communication protocol between TPS and Ceres - Perform autonomous movements with speed restrictions from Ceres - Validate the identification of objects on tracks
6. Units	SL18-455 or/and 456
7. STR Roles	Test team leader in Oslo, remote driver, on-board driver.
8. CAF Roles	Technical Leader, CAF engineers, remote driver

9. Risk Analysis	Risk Description	Mitigation
Risk 1	No specific risks identified.	
Risk 2		
Risk .. n		
10. Operational needs	We need to allocate the testing tracks to ensure safe movements without any other trams or obstacles in specific areas:  Autonomous movement tests will be performed in all tracks identified in the map. Tests will be executed at 10 km/h. Object detection tests will be performed in track 1.	

Interlocking must be ensured to enable tram movements between specified points.



11. Planning

Location	Day	Objetive	Tasks	Requirements
Holtet depot	Tuesday 21/04/2026 –	Validate TPS location	Validate positioning at different scenarios with RTK:	UT455 or 456 in Holtet, with a key to turn to mode 2.

		Wednesday 22/04/2026	enhancement with RTK	- Cold startup (track info) - Cab enabled - Moving	A driver in the UT under testing to move the UT. CAF personnel in the unit under testing New RTK antenna installed, F9P dev kit installed switched on and Holtet back-end switched on

	Holtet depot	Tuesday 21/04/2026 – Friday 24/04/2026	Perform autonomous movements without perception or speed supervision modules	Perform all available missions in depot without Ceres, forcing missions directly on the tram. Tests will be executed at a maximum speed of 10km/h.
				
				• Move to A
				  ○ From B:
				  ▪ H11 left, H2 right
				  ▪ B to C
				  ▪ Automatic change of cab
				  ▪ H11 right, H2 right
				  ▪ C to A
					UT455 or 456 in Holtet, with a key to turn to mode 2.
					
					A driver in the UT under testing to move the UT.
					
					CAF personnel in the UT under testing
					
					New RTK antenna installed, F9P dev kit installed switched on and Holtet back-end switched on

				▪ Stop point in A ○ From C: ▪ H11 right, H2 right ▪ C to A ▪ Stop point in A ○ From D: ▪ H2 left ▪ D to C ▪ Automatic change of cab ▪ H11 right, H2 right ▪ C to A ▪ Stop point in A • Move to B: ○ From A: ▪ H11 right, H2 right ▪ A to C ▪ Automatic change of cab ▪ H11 left, H2 right ▪ C to B	

				▪ Stop point in B ○ From C: ▪ H11 left, H2 right ▪ C to B ▪ Stop point in B ○ From D: ▪ H2 left ▪ D to C ▪ Automatic change of cab ▪ H11 left, H2 right ▪ C to B ▪ Stop point in B • Move to C: ○ From A: ▪ H11 right, H2 right ▪ A to C ▪ Stop point in C ○ From B: ▪ H11 left, H2 right ▪ B to C	

				▪ Stop point in C ○ From D: ▪ H2 left ▪ D to C ▪ Stop point in C • Move to D: ○ From A: ▪ H11 right, H2 right ▪ A to C ▪ Automatic change of cab ▪ H2 left ▪ C to D ▪ Stop point in D ○ From B: ▪ H11 left, H2 right ▪ B to C ▪ Automatic change of cab ▪ H2 left ▪ C to D ▪ Stop point in D ○ From C:	

				▪ H2 left ▪ C to D ▪ Stop point in D	
	Holtet depot	Thursday 23/04/2026	Validate OTIV and TPS communication protocol and object recording	At standstill, OTIV communication protocol should be validated. Forcing different objects in front of the tram, different recordings must be done. Objects correct identification and publishing must be validated. Static recording: - Place different objects in front of the tram: dummy, person, bicycle… - Move the objects Dynamic recording: - Place different objects next to the track	UT455 or 456 in Holtet, with a key to turn to mode 2. A driver in the UT under testing to move the UT. CAF personnel in the UT under testing. New RTK antenna installed, F9P dev kit installed switched on and Holtet back-end switched on Objects movement on the track.
	Holter depot	Thursday 23/04/2026 – Friday 24/04/2026	Validate the correct communication protocol between TPS and Ceres and	Validate the communication protocol with Ceres. Select a mission to be executed from Ceres.	UT455 or 456 in Holtet, with a key to turn UT455 to mode 2.

				autonomous missions	Validate variables are exchanged correctly and TPS enters in autonomous mode and performs the mission	A driver in the unit under testing to move the UT. CAF personnel in the unit under testing New RTK antenna installed, F9P dev kit installed switched on and Holtet back-end switched on Personnel in Ceres control center
	Holter depot	Thursday 23/04/2026 – Friday 24/04/2026	Validate speed restrictions from Ceres	Mission executions from Ceres limiting operational speed to 10 km/h temporally and validation that the speed is not exceeded.	UT455 in Holtet, with a key to turn UT455 to mode 2. A driver in the unit under testing to move the UT. CAF personnel in the unit under testing New RTK antenna installed, F9P dev kit installed switched on and Holtet back-end switched on

	Holter depot	Friday 27/04/2026	Validate the identification of objects on tracks	Place an object on the track and start a new mission. Object identification and tram stop validation	UT455 or 456 in Holtet, with a key to turn UT455 to mode 2. A driver in the unit under testing to move the UT. CAF personnel in the unit under testing New RTK antenna installed, F9P dev kit installed switched on and Holtet back-end switched on

12. Configuration Management	Equipment (Mode 2)	Initial SW version(s)
Eq. 1	CERES	0.2.4
Eq. 2	TPS	00.02
Eq. 3	PLC	1.08

Eq. 4	OTIV	2.2.3
Eq. .. n		

2. BLOCK 2

1. Updated info in Block 1	N/A
2. Description of the results (summary)	Tests summary: 1. **RTK Positioning Validation** RTK functionality was successfully validated in all tested scenarios, including cold startup conditions. RTK corrections were correctly applied, resulting in accurate and stable localization of the TPS throughout the tests. 2. **Autonomous Movements in Depot (without perception/speed supervision)** Most planned autonomous missions were executed successfully across the different depot paths and cab change scenarios. However, not all missions could be fully validated. Issues were identified in the algorithm parametrization, affecting smoothness and consistency of tram movements. Dynamic behaviour

requires further tuning to ensure homogeneous performance across different conditions, particularly on **flat, uphill, and downhill sections**.

3. **PER Validation – OTIV and TPS Communication**
   The communication protocol between OTIV and TPS was validated, and multiple static and dynamic object detection tests were performed. While the protocol itself functioned correctly, several issues were identified:
   a. Certain objects (e.g. cones with or without flags, columns with reflective cards) were incorrectly classified.
   b. Delays in data reception at the TPS impacted correct processing by the TPS algorithms.
4. **TPS–Ceres Communication and Mission Execution**
   A full autonomous mission executed from Ceres was not validated due to time constraints, and these tests were postponed for laboratory validation. Nevertheless, a test from tram was performed successfully, with the speed limit correctly respected. As observed in depot-only tests, motion dynamics require improvement to achieve smoother behaviour in future software versions.
5. **Object Identification on Track**
   Object placement on the track and subsequent mission execution confirmed that the system is capable of detecting objects and triggering a tram stop. Further refinement is required to improve robustness and classification accuracy.

Conclusions and Next Steps

	The validation campaign confirmed correct RTK operation and basic functionality of autonomous movements and communication interfaces. However, several functional and performance improvements are still required, particularly in **motion smoothness**, **perception classification accuracy**, **data latency handling**, and **full mission execution from Ceres**.	
6. Configuration Management	Equipment (Mode 2)	Final SW version(s)
Eq. 1	CERES	0.2.4
Eq. 2	TPS	01.00
Eq. 3	PLC	1.14
Eq. 4	OTIV	2.2.3

Eq. .. n		
7. Lessons learnt		
8. ACTIONS	A new test campaign will be planned to close all open points and to test the activities that were not done in actual tests	

Code	TD_CAF_0035
Vehicle / Contract	SL18 R2DATO // ALIVE
Concept	ALIVE Testing Description

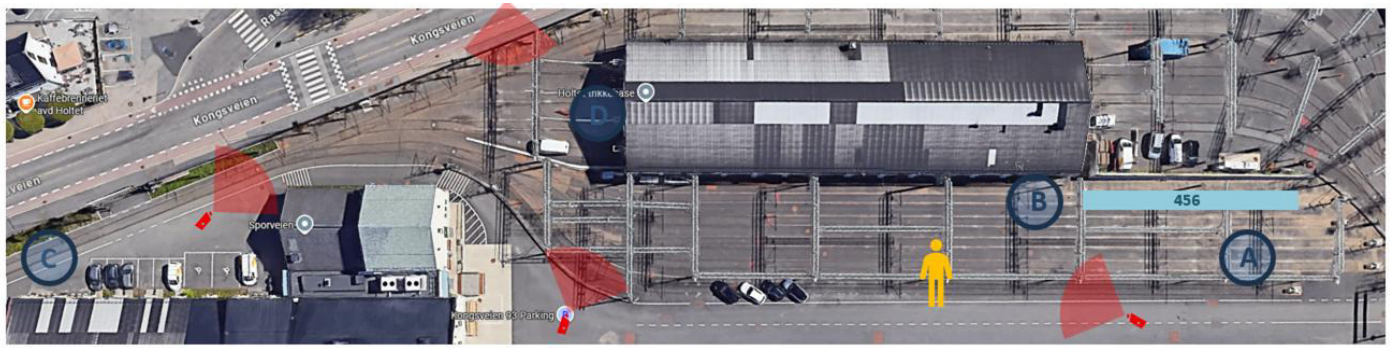
EDITION CONTROL

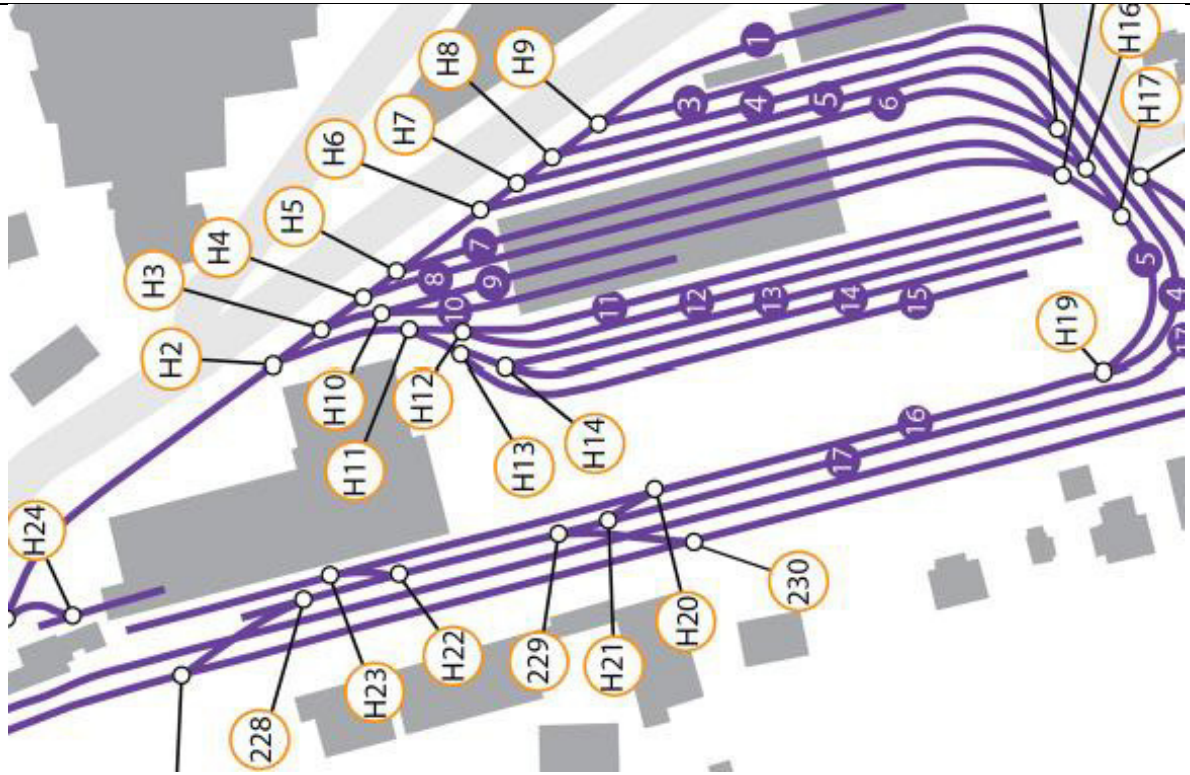
EDITION	REASON	DATE
-	First issue	10/06/2026
A	Block 2 updated	2026/06/22

Prepared by: Name: Nacho Celaya Date: 27/10/2023	Reviewed by: Name: Dusan Patrik Klago Date: 27/10/2023

1. BLOCK 1

1. Title	TPS functionalities final tests	
2. Technical Leader	Josune Aranburu	
3. Test Type	Type 2.2	
4. Subsystems involved	TPS, CERES, TCMS subsystems, OTIV	
5. Description of the Test	The objective of the test is: - Validate all possible missions executions from Ceres - Validate the correct obstacle detection during the missions - Validate correct cancellations from Ceres and from TPS	
6. Units	SL18-455 and 456	
7. STR Roles	Test team leader in Oslo, remote driver, on-board drivers.	
8. CAF Roles	Technical Leader, CAF engineers	
9. Risk Analysis	Risk Description	Mitigation
Risk 1	No specific risks identified.	

Risk 2		
Risk .. n		
10. Operational needs	We need to allocate the testing tracks to ensure safe movements without any other trams or obstacles in specific areas:  Autonomous movement tests will be performed between points A, B, C and D, in all tracks identified in the map. Tests will be executed at an operational speed of 10 km/h, with a margin of +/-2 km/h. Depot maximum speed of 15 km/h will not be exceeded. Object detection tests will be performed in track 11, with the dummy. Interlocking must be ensured to enable tram movements between specified points.	



11. Planning

Location	Day	Objetive	Tasks	Requirements
Holter depot	Tuesday 16/06/2026	Validate the correct mission	Validation of all possible mission executions executing from Ceres.	UT455 in Holtet, with a key to turn UT455 to mode 2.

		to Thursday 18/06/2026	execution from Ceres	Validate variables are exchanged correctly between tram and Ceres and missions are performed correctly. When mission reaches the end point, Ceres is informed and mission ended message is shown. Many missions must be performed to ensure that there are no issues in any of them. Available missions: 1. A – B 2. B – A (mannequin on track 14) 3. A – C 4. C – A (mannequin on track 14) 5. A – D 6. D – A (mannequin on track 14) 7. B – C 8. C – B 9. B – D 10. D – B 11. C – D 12. D – C	Two drivers in the unit under testing to move the UT, one in each cab. CAF personnel connected remotely to the tram F9P dev kit installed switched on and Holtet back-end switched on Personnel in Ceres control center Personnel in trackside to move the dummy

				In missions that end in point A, object identification and tram stop validation will be done, locating the mannequin in track 14.	
	Holter depot	Tuesday 16/06/2026 to Thursday 18/06/2026	Validate the correct cancel commands from Ceres	Validation that if a mission is cancelled from Ceres during execution, the process ends successfully. Place the mannequin on track 14 and start a new mission from C to A. Object identification and tram stop validation. Once the tram is stopped, cancel the mission from Ceres and validate that the mission ends successfully in Ceres. Program a new mission from A to C. Validate that the mission performs correctly	UT455 in Holtet, with a key to turn UT455 to mode 2. Two drivers in the unit under testing to move the UT, one in each cab. CAF personnel connected remotely to the tram F9P dev kit installed switched on and Holtet back-end switched on Personnel in Ceres control center Personnel in trackside to move the dummy
	Holter depot	Tuesday 16/06/2026	Validate the error of the mission in	Validation that if a mission is not finished because there has been an error in the TPS and exits from	UT455 in Holtet, with a key to turn UT455 to mode 2.

	to Thursday 18/06/2026	Ceres if an error happens in the TPS and exits from autonomous	autonomous, Ceres finishes the mission with error. Place the mannequin on track 14 and start a new mission from C to A. Object identification and tram stop validation. Once the tram is stopped, reset the TPS (remote command) to exit from autonomous and check in Ceres station that the mission ends with error. Program a new mission from A to C. Validate that the mission performs correctly	Two drivers in the unit under testing to move the UT, one in each cab. CAF personnel connected remotely to the tram F9P dev kit installed switched on and Holtet back-end switched on Personnel in Ceres control center Personnel in trackside to move the dummy
Holter depot	Tuesday 16/06/2026 to Thursday 18/06/2026	Validate the error of the mission in Ceres if the TPS cancels the mission	Validation that if a mission is not finished because the TPS has cancelled a mission, Ceres finishes the mission with error. Place the mannequin on track 14 and start a new mission from C to A. Object identification and tram stop validation.	UT455 in Holtet, with a key to turn UT455 to mode 2. Two drivers in the unit under testing to move the UT, one in each cab. CAF personnel connected remotely to the tram

					Once the tram is stopped, a localization error must be forced in the TPS and check in Ceres station that the mission ends with error. Program a new mission from A to C. Validate that the mission performs correctly	F9P dev kit installed switched on and Holtet back-end switched on Personnel in Ceres control center Personnel in trackside to move the dummy

12. Configuration Management	Equipment (Mode 2)	Initial SW version(s)
Eq. 1	CERES	Core: v0.3.4 HMI: v0.3.5
Eq. 2	TPS	S.E3.91.0008: v00.11
Eq. 3	PLC	1.26
Eq. 4	GRDM - ORDM	00.16

Eq. .. n		

2. BLOCK 2

1. Updated info in Block 1	TPS version correction, v0.11 was installed at the beginning of the tests.
2. Description of the results (summary)	Tests summary: The planned test campaign was carried out over three consecutive days in accordance with the activities defined in the planning section. During the first day, all missions listed in Annex Test1 were successfully executed and validated. 2026/06/16 results summary:

Test Run	Mission ID	Execution result (OK/ERROR)	Notes
1	A – B	OK	13:15 exec: OK.
2	B – A	OK	13:35 exec: OK
3	A – C	OK	13:40 exec: OK
4	C – A	OK	13:44 exec: OK
5	A – D	OK	13:47 exec: OK
6	D – A	OK	13:50 exec: OK
7*	A – B*	OK	13:57 exec: OK

8	B – C	OK	14:03 exec: OK
9	C – B	OK	14:06 exec: OK
10	B – D	OK	14:08 exec: OK
11	D – B	OK	14:13 exec: OK
12*	B – C*	OK	14:17 exec: OK
13	C – D	OK	14:21 exec: OK
14	D – C	OK	14:23 exec: OK

Error test case defined in Annex Test2 also was executed successfully.

However, the error test cases defined in Annex Test3 and Test4 did not pass due to an incompatibility associated with the software version installed on the CERES server.

On the second day, after updating the CERES server software version to version v0.3.5, the error test cases from Annex Test3 and Annex Test4 were successfully completed. Nevertheless, several tests that had previously passed began to fail unexpectedly. As a result, the testing activities were stopped in order to investigate and identify any changes introduced since the previous day.

During the third day, the CERES monitoring HMI was connected to support the diagnostic activities. The same unexpected behaviour was observed, and a detailed analysis was performed. The investigation revealed that the communication link between the tram and the train was saturated, resulting in packet losses and unstable system behaviour. After restricting remote connections to only those strictly required for monitoring purposes, communication performance returned to normal and all planned test cases were successfully completed.

Test Run	Mission ID	Execution result (OK/ERROR)	Notes
1	A – B	OK	9:39: OK
2	B – A	OK	10:41: OK
3	A – C	OK	10:44: OK
4	C – A	OK	11:37: OK
5	A – D	OK	11:40: OK
6	D – A	OK	11:44: OK
7*	A – B*	OK	11:50: OK
8	B – C	OK	11:55: OK
9	C – B	OK	11:57: OK
10	B – D	OK	12:00: OK
11	D – B	OK	12:07: OK
12*	B – C*	OK	12:11: OK
13	C – D	OK	12:14: OK
14	D – C	OK	12:16: OK

Test 2: 12:21 exec: OK

Test 3: 12:28 exec: OK

Test 4: 12:23 exec: OK

	Conclusion Overall, after the resolution of the software version issue, the communication saturation problem, and the speed calculation adjustment, all planned tests were completed successfully, and the system performance met the expected requirements. New Ceres HMI Version A software issue causing application crashes was identified in the previous HMI version. The root cause was traced to the video streaming functionality. The issue has been corrected in version v0.3.6, and no further occurrences were observed during the executed tests.	
3. Configuration Management	Equipment (Mode 2)	Final SW version(s)
Eq. 1	CERES	Core: v0.3.5 HMI: v0.3.6
Eq. 2	TPS	S.E3.91.0008: v00.12

Eq. 3	PLC	1.27
Eq. 4	GRDM - ORDM	00.16
4. Lessons learnt		
5. ACTIONS	Repeat the test to confirm system stability and correct functionality after the identified communication issue has been resolved. During the revalidation activities, remote connections shall be restricted to only those strictly required for testing purposes in order to prevent network congestion and connectivity-related issues. Considering the results obtained during the test campaign, no software or system modifications will be implemented before or during the InnoTrans demonstration period.	

ANNEX 1:
TESTING PROCEDURE AND RESULTS

	To	Alive test team
	From	JOSUNE Aranburu
	Date	2026.07.222026.06.18
	Isuue	TPS final tests description and results
	Project:	R2DATO
	Ref:	ALIVE_TD_CAF_0035
	Vers	00.00

1 INTRODUCTION 2

2 TEST DESCRIPTION 2

2.1 TEST1 - Correct mission executions including obstacle detection 2

2.1.1 TEST1.01 A -> B 2
2.1.2 TEST1.02 B -> A 2
2.1.3 TEST1.03 A -> C 3
2.1.4 TEST1.04 C -> A 3
2.1.5 TEST1.05 A -> D 3
2.1.6 TEST1.06 D -> A 4
2.1.7 TEST1.07 A -> B 4
2.1.8 TEST1.08 B -> C 5
2.1.9 TEST1.09 C -> B 5
2.1.10 TEST1.10 B -> D 5
2.1.11 TEST1.11 D -> B 5
2.1.12 TEST1.12 B -> C 6
2.1.13 TEST1.13 C -> D 6
2.1.14 TEST1.14 D -> C 6

2.2 TEST2 - Mission cancellation from Ceres 7

2.3 TEST3 - Error in the TPS and Ceres correct reaction 7

2.4 TEST4 - Mission cancellation from TPS 8

3 TEST EXECUTION RESULTS 8

3.1 TEST1 Execution results 8

3.1.1 Day 1 - 2026/06/16 8
3.1.2 Day 2 - 2026/06/17 9
3.1.3 Day 3- 2026/06/18 11

3.2 TEST 2 Execution results 15

3.2.1 Day 1 - 2026/06/16 15
3.2.2 Day 2 - 2026/06/17 15
3.2.3 Day 3- 2026/06/18 15

3.3 TEST3 Execution results 15

3.3.1 Day 1 - 2026/06/16 15
3.3.2 Day 2 - 2026/06/17 15
3.3.3 Day 3- 2026/06/18 15

3.4 TEST4 Execution results 16

3.4.1 Day 1 - 2026/06/16 16
3.4.2 Day2 - 2026/06/17 16
3.4.3 Day 3- 2026/06/18 16

	To	Alive test team
	From	JOSUNE Aranburu
	Date	2026.07.222026.06.18
	Isuue	TPS final tests description and results
	Project:	R2DATO
	Ref:	ALIVE_TD_CAF_0035
	Vers	00.00

1 INTRODUCTION

The objective of the present note is to define the procedure to execute all final tests defined in ALIVE_TD_CAF_0035_TPS_final_tests.docx document, to validate the correct execution of autonomous movements.

Following tests will be validated:

1. TEST1 - Correct mission executions including obstacle detection and tram stop validation
2. TEST2 - Mission cancellation from Ceres
3. TEST3 - Error in the TPS and Ceres correct reaction
4. TEST4 - Mission cancellation from TPS

2 TEST DESCRIPTION

2.1 TEST1 - Correct mission executions including obstacle detection

These tests aim to validate the correct execution of all missions executed from Ceres, without forcing any error condition. To execute and validate all possible missions, next steps will be checked once each mission is executed:

Prerequisites

T55 located at point A, on **track 14,** cab B pointing towards point C**.**

Test execution

2.1.1 TEST1.01 A -> B

- A mission is programmed in Ceres station from point A to point B (route A-B)
  - No initial sequences
  - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off
- Switch point movement must be done to enable the movement to point B
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point B
- Unit stops at point B and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.2 TEST1.02 B -> A

- Dummy placed in track 14
- A mission is programmed in Ceres station from point B to point A (route B-A)
  - No initial sequences
  - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off

- Switch point movement must be done to enable the movement to point A
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point A
- The unit stops at dummy location
- Dummy removed from the track
- Mission continues to point A
- Unit stops at point A and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.3 TEST1.03 A -> C

- A mission is programmed in Ceres station from point A to point C (route A-C)
    - No initial sequences
    - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Unit stops at point C and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.4 TEST1.04 C -> A

- Dummy placed in track 14
- A mission is programmed in Ceres station from point C to point A (route C-A)
    - No initial sequences
    - No end sequences
- **Cab A** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point A
- Validate the movement in the map of Ceres application
- The unit stops at dummy location
- Dummy removed from the track
- Mission continues to point A
- Unit stops at point A and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.5 TEST1.05 A -> D

- A mission is programmed in Ceres station from point A to point D (route A-D)
    - No initial sequences
    - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application

- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off
- Switch point movement must be done to enable the movement to point D (workshop)
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point D
- Unit stops at point D and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.6 TEST1.06 D -> A

- Dummy placed in track 14
- A mission is programmed in Ceres station from point D to point A (route D-A)
    - No initial sequences
    - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off
- Switch point movement must be done to enable the movement to point A
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point A
- The unit stops at dummy location
- Dummy removed from the track
- Mission continues to point A
- Unit stops at point A and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.7 TEST1.07 A -> B

A -> B mission is repeated to reach point B. Initial and end sequences will be validated

- A mission is programmed in Ceres station from point A to point B (route A-B)
    - Doors open/close
    - Doors open/close
- Doors open and close sequence is performed on the tram
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off
- Switch point movement must be done to enable the movement to point B
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point B
- Unit stops at point B and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.8 TEST1.08 B -> C

- A mission is programmed in Ceres station from point B to point C (route B-C)
  - No initial sequences
  - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Unit stops at point C and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.9 TEST1.09 C -> B

- A mission is programmed in Ceres station from point C to point B (route C-B)
  - No initial sequences
  - No end sequences
- **Cab A** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point B
- Validate the movement in the map of Ceres application
- Unit stops at point B and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.10 TEST1.10 B -> D

- A mission is programmed in Ceres station from point B to point D (route B-D)
  - No initial sequences
  - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off
- Switch point movement must be done to enable the movement to point D (workshop)
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point D
- Unit stops at point D and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.11 TEST1.11 D -> B

- A mission is programmed in Ceres station from point D to point B (route D-B)
  - No initial sequences
  - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C

- Validate the movement in the map of Ceres application
- Tram stops at point C and cab change is done enabling **cab A**. Emergency lights are switched off
- Switch point movement must be done to enable the movement to point B
- Approximately 55 seconds later, bell sounds and emergency lights are switched on
- Mission continues to point B
- Unit stops at point B and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.12 TEST1.12 B -> C

B -> C mission is repeated to reach point C. Initial and end sequences will be validated

- A mission is programmed in Ceres station from point B to point C (route B-C)
  - Initial sequence: Doors open/close
  - End sequence: Doors open/close
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Unit stops at point C and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.13 TEST1.13 C -> D

- A mission is programmed in Ceres station from point C to point D (route C-D)
  - No initial sequences
  - No end sequences
- **Cab A** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point D
- Validate the movement in the map of Ceres application
- Unit stops at point D and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.1.14 TEST1.14 D -> C

- A mission is programmed in Ceres station from point D to point C (route D-C)
  - No initial sequences
  - No end sequences
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Unit stops at point C and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.2 TEST2 - Mission cancellation from Ceres

These tests aim to validate that if a mission is cancelled from Ceres during execution, the process ends successfully.

Prerequisites

- T55 located at point C
- Place the mannequin on track 14

Test execution

- A mission is programmed in Ceres station from point C to point A (route C-A)
  - No initial sequences
  - No end sequences
- **Cab A** is enabled, bell sounds and emergency lights are switched on
- Object identification and tram stop validation.
- Once the tram is stopped, cancel the mission from Ceres
- Validate that the mission ends successfully in Ceres.
- Program a new mission from A to C (route A-C)
- Validate that the mission performs correctly

2.3 TEST3 - Error in the TPS and Ceres correct reaction

These tests aim to validate that if a mission is not finished because there has been an error in the TPS and exits from autonomous, Ceres finishes the mission with error.

Prerequisites

- T55 located at point C
- Place the mannequin on track 14

Test execution

- A mission is programmed in Ceres station from point C to point A (route C-A)
  - No initial sequences
  - No end sequences
- **Cab A** is enabled, bell sounds and emergency lights are switched on
- Object identification and tram stop validation.
- Once the tram is stopped, reset the TPS (remote command) to exit from autonomous
- Check in Ceres station that the mission ends with error.
- Program a new mission from A to C.
  - No initial sequences
  - No end sequences
- Validate that the mission performs correctly
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Unit stops at point C and emergency lights are switched off
- The correct end of mission is validated at Ceres station

2.4 TEST4 - Mission cancellation from TPS

These tests aim to validate that if a mission is not finished because the TPS has cancelled a mission, Ceres finishes the mission with error.

Prerequisites

- T55 located at point C
- Place the mannequin on track 14

Test execution

- A mission is programmed in Ceres station from point C to point A (route C-A)
  - No initial sequences
  - No end sequences
- **Cab A** is enabled, bell sounds and emergency lights are switched on
- Object identification and tram stop validation.
- Once the tram is stopped, force segment state error in TPS (remote command)
- Check in Ceres that the mission ends with error.
- Program a new mission from A to C.
  - No initial sequences
  - No end sequences
- Validate that the mission performs correctly
- **Cab B** is enabled, bell sounds and emergency lights are switched on
- Tram starts to move towards point C
- Validate the movement in the map of Ceres application
- Unit stops at point C and emergency lights are switched off
- The correct end of mission is validated at Ceres station

3 TEST EXECUTION RESULTS

3.1 TEST1 Execution results

3.1.1 Day 1 - 2026/06/16

Test	Mission ID	Execution result (OK/ERROR)	Notes
TEST1.01	A – B	OK	13:15 exec: OK. - Obstacle merger cutoff: jun 16 11:25:29 cpud ALIVE[450]: Type: 0, Level: 2, ../Src/ipm_ob_brake_manager_runner.cpp::490, (IPM) (25914) CIpmObBrakeManagerRunner: ObstacleDetec TCO request set to TRUE) *Note 1: traction cutoff graphic
TEST1.02	B – A	OK	13:35 exec: OK *Note 2: dummy detection graphic

TEST1.03	A – C	OK	13:40 exec: OK *Note 3: CERES mission status and map screen
TEST1.04	C – A	OK	13:44 exec: OK
TEST1.05	A – D	OK	13:47 exec: OK - jun 16 11:50:14 cpud ALIVE[450]: Type: 0, Level: 2, ../Src/ipm_ob_brake_manager_runner.cpp::490, (IPM) (6810) CIpmObBrakeManagerRunner: ObstacleDetec TCO request set to TRUE
TEST1.06	D – A	OK	13:50 exec: OK
TEST1.07	A – B	OK	13:57 exec: OK - jun 16 11:59:03 cpud ALIVE[450]: Type: 0, Level: 1, ../Src/ipm_ob_base_runner_state.cpp::110, (IPM) (23341) GradientRunner MINOR error: CALC_ERR - jun 16 11:59:03 cpud ALIVE[450]: Type: 0, Level: 2, ../Src/ipm_ob_base_runner_state.cpp::130, (IPM) (23341) StatusReportRunner INFO CODE: FG_ERROR_MINOR,FG_INFO_NOTIF - jun 16 11:59:03 cpud ALIVE[450]: Type: 0, Level: 1, ../Src/ipm_ob_base_runner_state.cpp::110, (IPM) (23342) GradientRunner MINOR error: OK
TEST1.08	B – C	OK	14:03 exec: OK
TEST1.09	C – B	OK	14:06 exec: OK
TEST1.10	B – D	OK	14:08 exec: OK - jun 16 12:09:22 cpud ALIVE[450]: Type: 0, Level: 1, ../Src/ipm_ob_base_runner_state.cpp::110, (IPM) (42687) GradientRunner MINOR error: CALC_ERR
TEST1.11	D – B	OK	14:13 exec: OK
TEST1.12	B – C	OK	14:17 exec: OK
TEST1.13	C – D	OK	14:21 exec: OK
TEST1.14	D – C	OK	14:23 exec: OK

3.1.2 Day 2 - 2026/06/17

Test	Mission ID	Execution result (OK/ERROR)	Notes
TEST1.01	A – B	ERROR OK	12:13: ERROR - jun 17 10:13:13 cpud ALIVE[767]: Type: 0, Level: 1, ../Src/ipm_ob_base_runner_state.cpp::110, (IPM) (0) SpeedSupervisionRunner MINOR error: IN_DATA_SPEED_ERROR - jun 17 10:13:13 cpud ALIVE[767]: Type: 0, Level: 1, ../Src/ipm_ob_base_runner_state.cpp::110, (IPM) (0) ObsMergerRunner MINOR error: SPEED_ERR - jun 17 10:13:13 cpud ALIVE[767]: Type: 0, Level: 0, ../Src/ipm_system_failure_proced.cpp::187,

			(IPM) (0) ProceduresRunner(SFProc): Cab=OK, Speed=ERROR, Digimap=OK, BrakeManager SelfTest=OK -> Goa1+ System failure detected. 12:19: OK
TEST1.02	B – A	OK	12:22: OK
TEST1.03	A – C	OK	12:28 OK
TEST1.04	C – A	OK	12:33 OK - jun 17 10:35:18 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_mission_runner.cpp::541, (IPM) (35165) MissionRunner: TCO - Traction cutoff command applied. - jun 17 10:35:18 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_mission_runner.cpp::546, (IPM) (35165) MissionRunner: SB - Service brake command applied. - jun 17 10:35:18 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_mission_runner.cpp::551, (IPM) (35165) MissionRunner: EB - Emergency brake command applied.
TEST1.05	A – D	OK	12:42: OK
TEST1.06	D – A	OK	12:46: ERROR - jun 17 10:49:30 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_mission_runner.cpp::507, (IPM) (61826) MissionRunner: State changed from RUNNING to CANCELLED. (Mission: Id=914 Status=Running Code=Ok) - jun 17 10:49:30 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_mode_runner.cpp::424, (IPM) (61826) ModeRunner: AM mode exit requested by ATS[true] or MissionRnr[false]. 12:56: OK - jun 17 10:58:48 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/dsm_das_state_machine.cpp::412, (DSM) (13711) DAS state machine - Error reset - jun 17 10:58:48 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_brake_manager_runner.cpp::443, (IPM) (13712) CIpmObBrakeManagerRunner: SpeedSuperv TCO request set to TRUE - jun 17 10:58:48 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_brake_manager_runner.cpp::448, (IPM) (13712) CIpmObBrakeManagerRunner: SpeedSuperv SBC request set to TRUE - jun 17 10:58:48 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_brake_manager_runner.cpp::453,

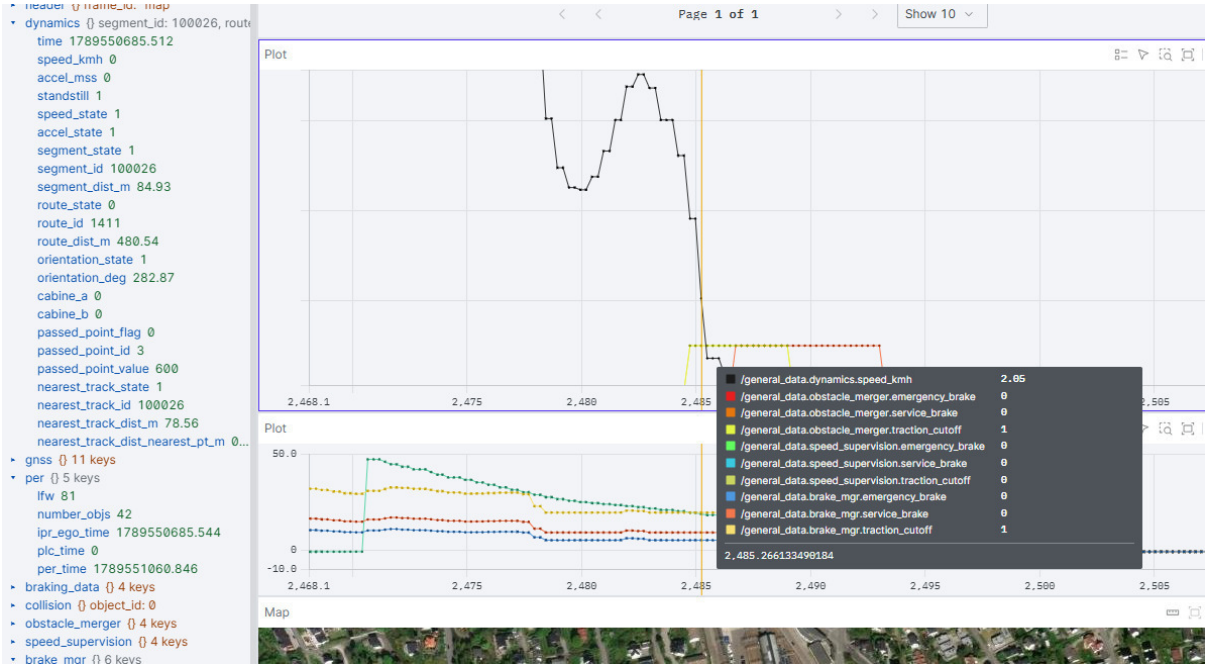
			(IPM) (13712) CIpmObBrakeManagerRunner: SpeedSuperv EBC request set to TRUE - jun 17 10:58:53 cpud ALIVE[825]: Type: 0, Level: 2, ../Src/ipm_ob_base_runner_state.cpp::130, (IPM) (13797) ObsMergerRunner INFO CODE: NO_CABINE - jun 17 10:58:53 cpud ALIVE[825]: Type: 0, Level: 0, ../Src/ipm_ob_mode_runner_conditions.cpp::59, (IPM) (13797) ModeRunner: SB from PWR conditions changed [Cab][0x00].
TEST1.07	A – B	OK	13:10: OK
TEST1.08	B – C	OK	13:15: OK
TEST1.09	C – B	OK	13:17: OK
TEST1.10	B – D	OK	13:25: OK
TEST1.11	D – B	OK	13:27: OK
TEST1.12	B – C	OK	13:31: OK
TEST1.13	C – D	OK	13:34: OK
TEST1.14	D – C	OK	13:36: OK

3.1.3 Day 3- 2026/06/18

Test	Mission ID	Execution result (OK/ERROR)	Notes
TEST1.01	A – B	ERROR OK	9:35: ERROR - jun 18 07:35:19 cpud ALIVE[634]: Type: 0, Level: 0, ../Src/ipm_ob_mode_runner_conditions.cpp::158, (IPM) (31299) ModeRunner: AM not possible: SpeedSupervision Obstacle ComAts 9:39: OK
TEST1.02	B – A		9:46: - jun 18 07:46:32 cpud ALIVE[1101]: Type: 0, Level: 2, ../Src/ipm_ob_mission_runner.cpp::507, (IPM) (18349) MissionRunner: State changed from RUNNING to CANCELLED. (Mission: Id=1114 Status=Running Code=Ok) 10:41: OK
TEST1.03	A – C		10:44: OK
TEST1.04	C – A		11:37: OK
TEST1.05	A – D		11:40: OK
TEST1.06	D – A		11:44: OK
TEST1.07	A – B*		11:50: OK

TEST1.08	B – C		11:55: OK
TEST1.09	C – B		11:57: OK
TEST1.10	B – D		12:00: OK
TEST1.11	D – B		12:07: OK
TEST1.12	B – C		12:11: OK
TEST1.13	C – D		12:14: OK
TEST1.14	D – C		12:16: OK

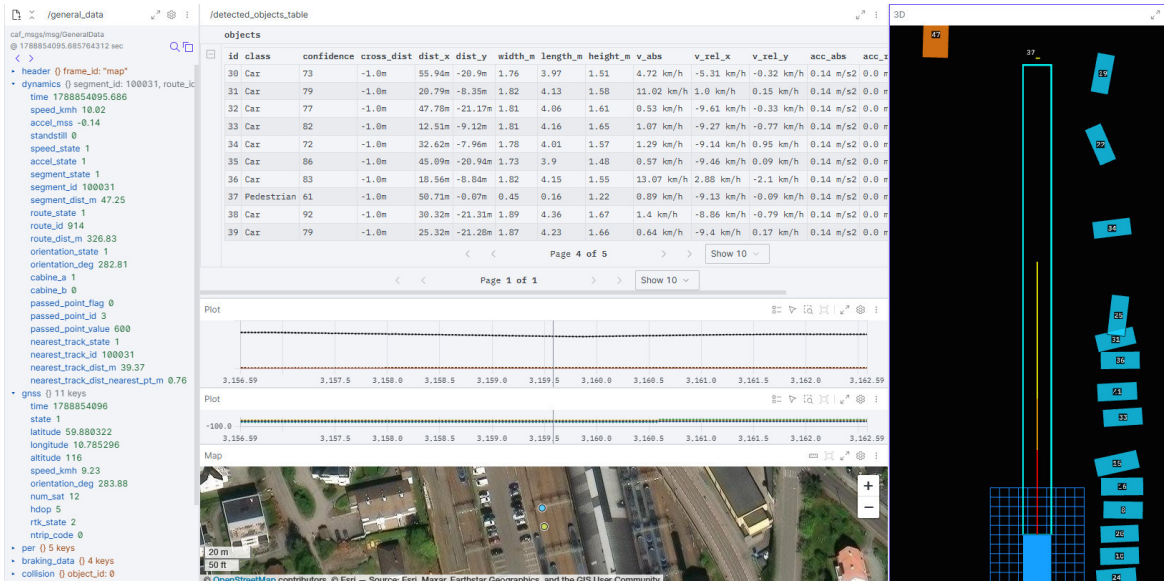
*Note1



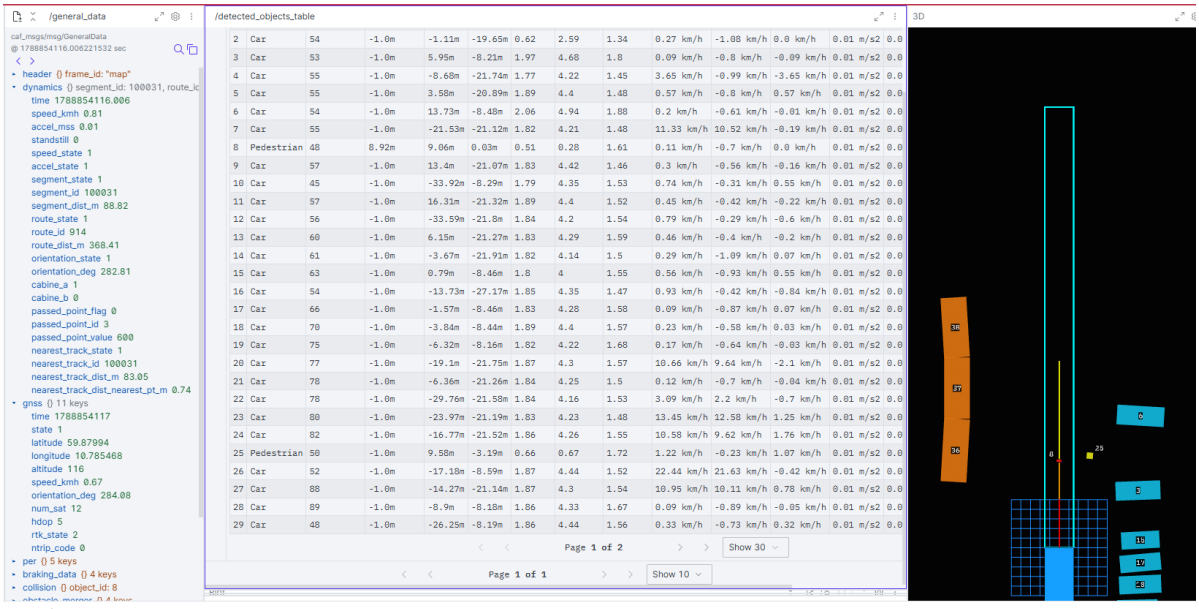
*Note2

Dummy detected at 50m:

	To	Alive test team
	From	JOSUNE Aranburu
	Date	2026.07.222026.06.18
	Isuue	TPS final tests description and results
	Project:	R2DATO
	Ref:	ALIVE_TD_CAF_0035
	Vers	00.00

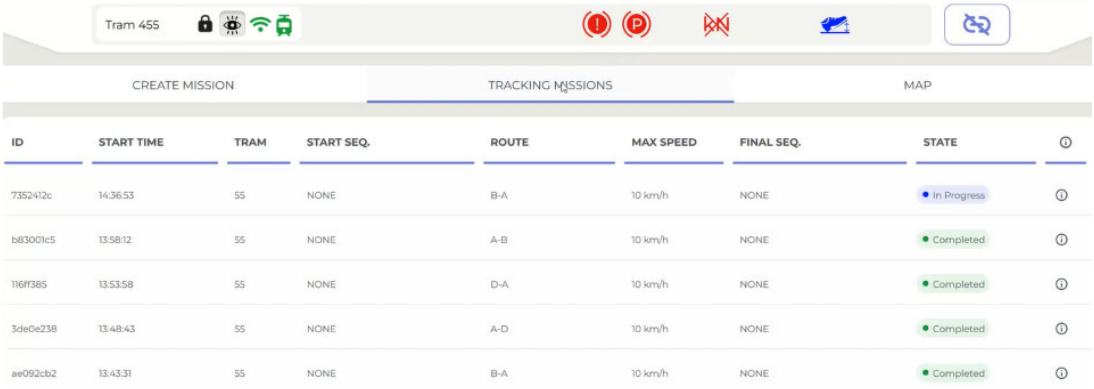


Tram stopped at 9m:

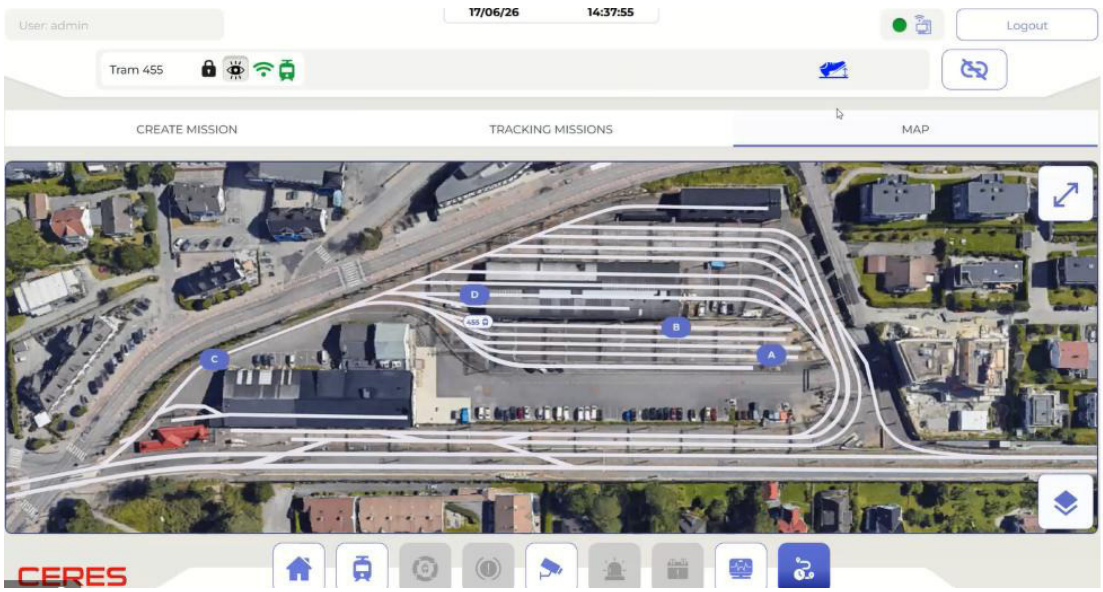


*Note3

CERES mission status screen:



CERES mission map screen



3.2 TEST 2 Execution results

3.2.1 Day 1 - 2026/06/16

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC02	A – C C – A	OK	14:28: OK

3.2.2 Day 2 - 2026/06/17

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC02	A – C C – A	OK	9:39: OK

3.2.3 Day 3- 2026/06/18

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC02	A – C C – A	OK	9:39: OK

3.3 TEST3 Execution results

3.3.1 Day 1 - 2026/06/16

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC03	A – C C – A	OK	14:34: ERROR

3.3.2 Day 2 - 2026/06/17

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC03	A – C C – A	OK	12:28: OK

3.3.3 Day 3- 2026/06/18

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC03	A – C C – A	OK	14:20: OK

3.4 TEST4 Execution results

3.4.1 Day 1 - 2026/06/16

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC03	A – C C – A	OK	12:33: ERROR – CANCEL not receive from CERES

3.4.2 Day2 - 2026/06/17

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC03	A – C C – A	OK	14:25: OK

3.4.3 Day 3- 2026/06/18

Test	Mission ID	Execution result (OK/ERROR)	Notes
TC03	A – C C – A	OK	11:25: OK