MODURBAN

FP6 Project: IP 516380

EC Contract n°: TIP4-CT-2005-516380

MODONBOARD SUBPROJECT

– DELIVERABLE REPORT –

Deliverable ID:	**D13**
Deliverable Title:	Demonstration on test track
Responsible partner:	ALSTOM
Contributors:	WP2 Partners

Document Information

Document Name: Demonstration on test track
Document ID: D13
Revision: V10
Revision Date: 2009-03-02
Author: ALSTOM
Security: PUBLIC

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Documents history

Revision	Date	Modification	Author
V0	12-09-08	Creation	ALSTOM
V1	26-09-08	Addings after meeting in Madrid 17/09/2008	ALSTOM
V5	13-10-08		ALSTOM
V7	20-10-08	Train interfaces update after integration test	ALSTOM
V8	22-10-08	On line runs description see chapter 3.4	ALSTOM
V9	22-10-08	Upgrade of electrical interface (DIR and ATO)	ALSTOM
V10	2-03-09	Review	ALSTOM

The scope of the document applies to:

Metro systems only	Metro and Light Rail			Light Rail only
	With no differenciation	*With specific adaptation(s)/recommendation(s) (1)*		
		For metro	*For Light Rail*	
X				

(1) – Put a [D] if these adaptations/recommendations are present in the document and a [L] if they will have to be detailed later.

SECTION I – DELIVERABLE SUMMARY

D13 Intelligent driving prototyping	
Deliverable ID , associated WP & Subproject	D13: Demonstration on test track MODONBOARD / WP2
Type of Deliverable	Specification
Input / Starting stage	
Output / Final stage	

Lead partner(s)	
Achievement to date (%)	100%
Expected date of achievement	
Type of exploitation	
Exploitation potential	
Protection	*Not Relevant*
Protection date	*Not Relevant*

IP's	***Partners, (type, identification, date)***
Pre-existing Know-How	
Exploitation Rights	

Associated Risk analysis	***Type, solution envisaged, action, actors***	***Actual Reduction***
Before start		
During task implementation		

D13: Intelligent driving prototyping

Deliverable Abstract

Objective of WP2 is to think about an intelligent driving to tackle with the problem of time varying train parameters, ageing of train and discrepancies on train parameters of a whole fleet. Intelligent driving will modify the train control in case the command is no more able to reach asked ATC performances.

Objective of D13 is to specify the site test installation.

Associated Milestone (if relevant):

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TABLE OF FIGURES

SECTION 2 – DELIVERABLE DETAILED DESCRIPTION

1. INTRODUCTION

Objectives of this document are to define the on Metro-Madrid test of the intelligent driving function Prototype.

1.1. Document Organisation:

This document is made of 5 clauses:

1 – Introduction This clause addresses the objectives of the document.

2 – Test bench installation This clause describes the installation on site.

3 – On site test strategy This clause describes the scenario for the different part of the project

4 – Test results This clause describes the result of the tests define in the section 3

5 – Demonstration This clause gives on overview of the demonstration.

1.2. Objectives:

This document forms is part of the Work Package 2 “Onboard Intelligent Driving” which objectives are, according to the [DOW] to define and develop an intelligent automatic driving for the ATO in order to tackle with the problem of time varying train parameters, ageing of trains and discrepancies between trains in a fleet.

1.3. Glossary

AC	**Alternating Current**
ATO	**Automatic Train Operation**
DOT	**Direction Of Traffic**
HMI	**Human Machine Interface**
ID	**Intelligent Driving**
PID	**Proportional – Integral - Derivative**
PK	**Kilometric Point**
RPS	**Rapid Prototyping System**

2. Test bench installation

2.1. On track installation

2.1.1. Beacons along the track (Herrera Oria/Barrio del pilar)

According to last meeting the beacon layout to the track is as follow

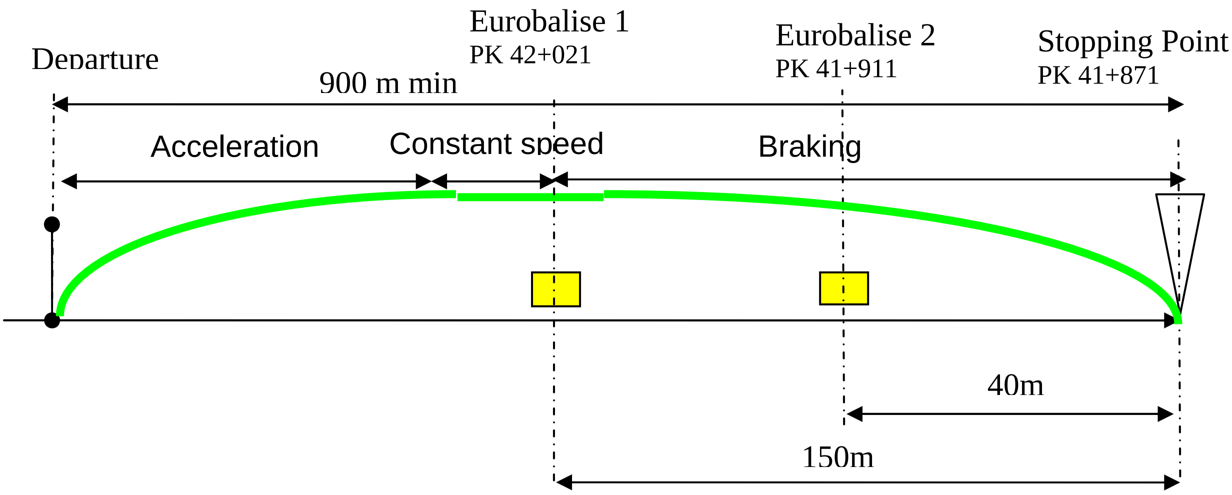


Figure 1. Beacon installation

2.1.2. Beacon height installation

The distance from top of beacon to top of rail is between 80 mm and 130 mm.
See figure "Antenna lateral view".

2.1.3. Beacon lateral installation

See under figure.

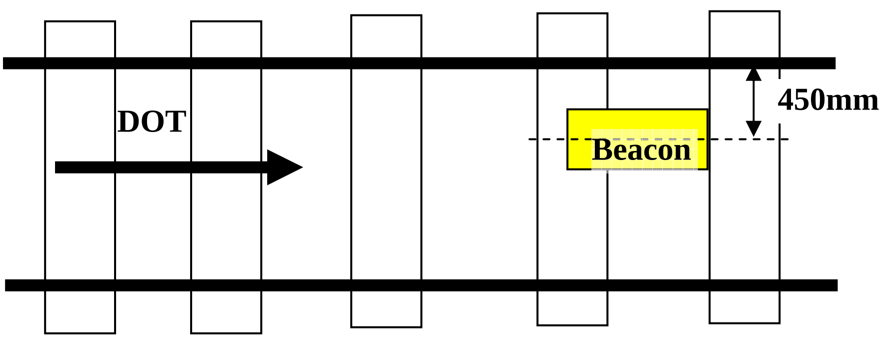
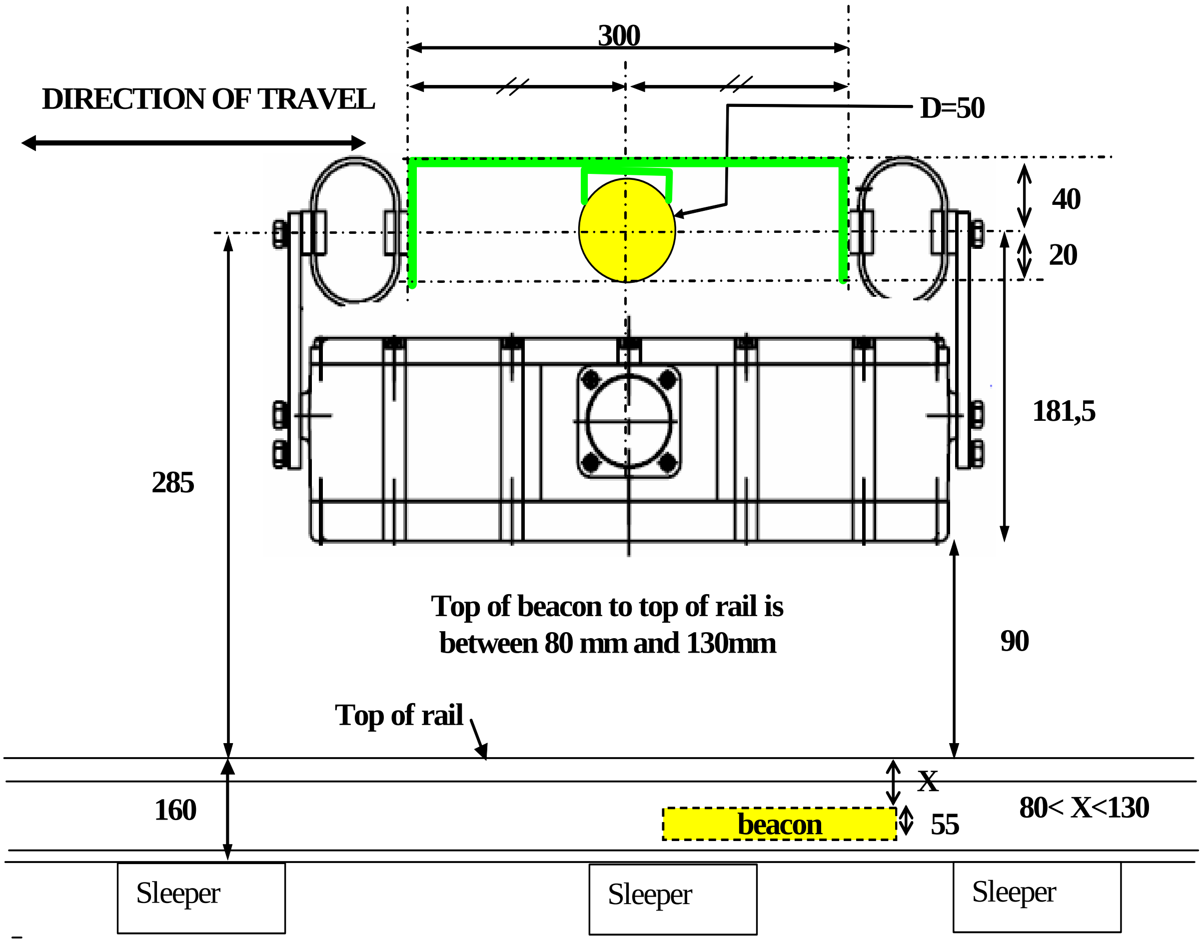


Figure 2. Beacon top view

2.2. Antenna on board installation

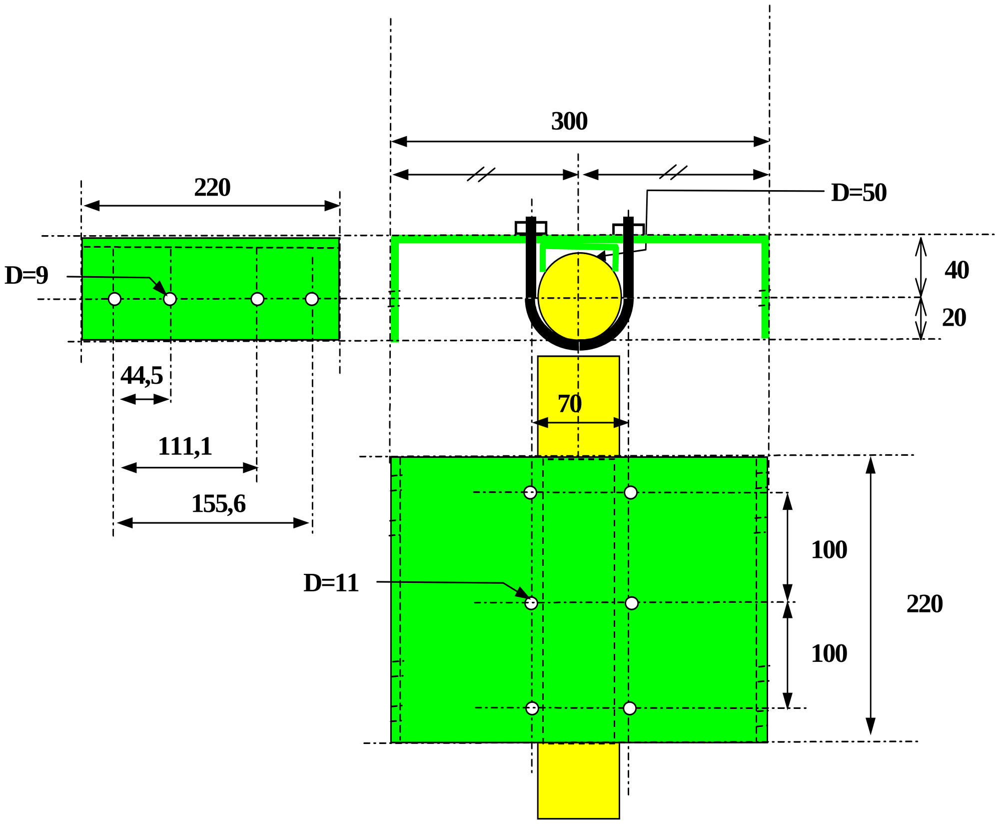
2.2.1. Lateral view of beacon installation



NOTE: All values are in millimeter.

Figure 3. Antenna lateral view (dimensions are given in mm)

2.2.2. Detail of antenna bracket



NOTE: All values are in millimeter.

Figure 4. Antenna bracket (dimensions are given in mm)

2.2.3. Top View of antenna on bogie.

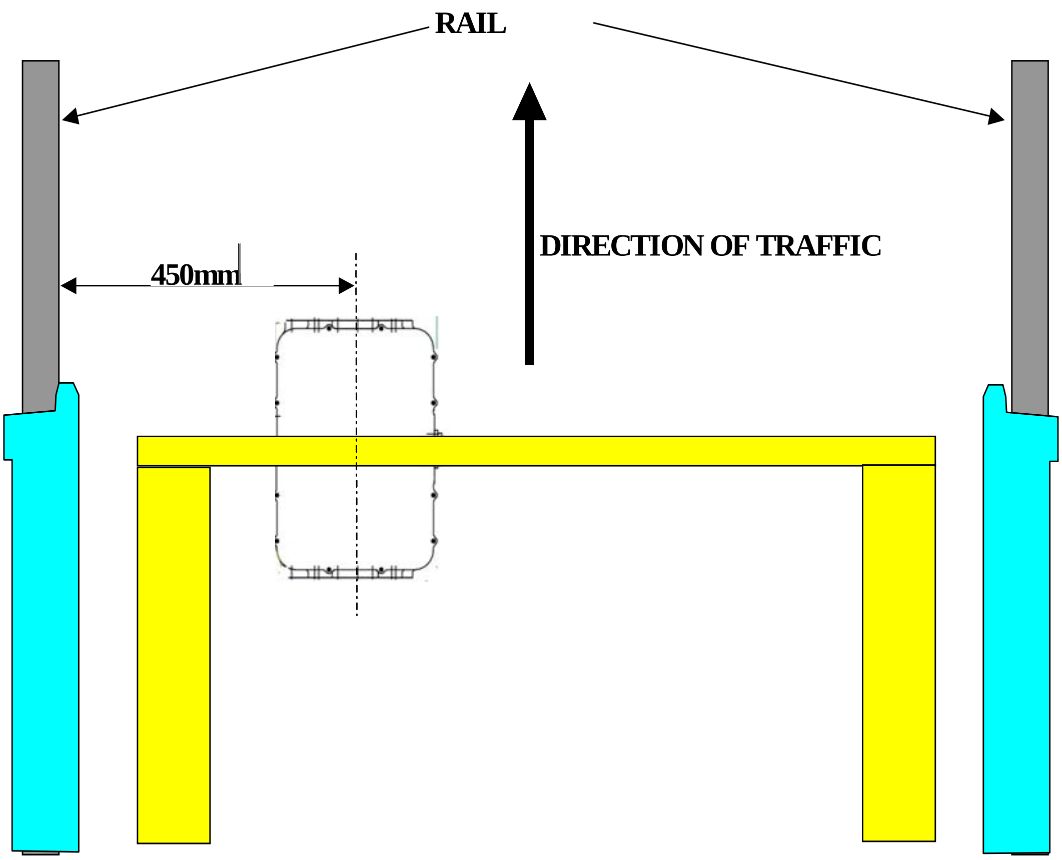


Figure 5. Antenna Top View

2.3. Electrical interface between Train and RPS

2.3.1. Connectors definition

Connector’s type: 12 pins terminal

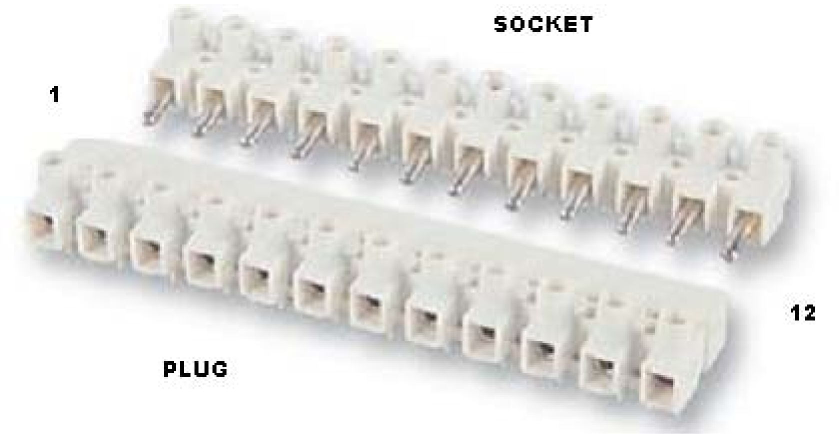


Figure 6. RPS connectors

2.3.2. Connectors assignment

		Plug 1		ODOMETER	
PIN	**WIRE**	**DESCRIPTION**	**Type**	**REMARK**	**Cable type**
1	1	Signal 15V1	Input	Odometre130	Twisted shielded pair 1
2	1	ref1	Input	Odometer130	
3	1&2	shielding	Input	Odometer130	
4	2	Signal 15V2	Input	Odometer130	Twisted shielded pair 2
5	2	ref2	Input	Odometer130	
6	3	signal 15V01	Input	Odometer130	Twisted shielded pair 3
7		spare			
8		spare			
9		spare			
10		spare			
11		spare			
12		spare			

		Plug 2			
PIN	**WIRE**	**DESCRIPTION**	**Type**	**REMARK**	**Cable type**
1	5	Output 0/-10V	Output	Electrical Brake	Twisted shielded pair 5
2	5	shielding	Output	Electrical Brake	
3	5	ref 0/10V	Output	Electrical Brake	
4		spare			
5		spare			
6		spare			
7		spare			
8		spare			
9		spare			
10		spare			
11	1	Contact ATO	Output	No potential contact	single wire 2 mm^2
12	1	Contact ATO	Output	Open when ID drive	single wire 2 mm^2

		Plug 3			
PIN	**WIRE**	**DESCRIPTION**	**Type**	**REMARK**	**Cable type**
1	1	spare			
2	1	Relay 1	Output	Pneumatic brake	single wire
3	1	Relay 2	Output	Pneumatic brake	single wire
4	1	Relay 3	Output	Pneumatic brake	single wire
5	1	Relay 1	Output	Traction	single wire
6	1	Relay 2	Output	Traction	single wire
7	1	Relay 3	Output	Traction	single wire
8	1	Relay 4	Output	Traction	single wire
9	1	Battery 110V	Input	Power	single wire 2 mm^2
10	1	Battery 0V	Input	power	single wire 2 mm^2
11	1	Direction	Output	Traction Direction	single wire 2 mm^2
12		spare			

2.3.3. Manual /ID Mushroom Push Button

This Push button allows the ID to take the hand on the train.
There are two separate circuits: One normally closes the other normally open.

Position	Normally close circuit	Normally open circuit
ID mode	Close	Open
Manual mode	Open	Close
	ID battery supply	Contact ATO

3. On site Test Strategy

3.1. Introduction

The test strategy is divided in three phases:

- On board integration test
- ATO Tuning
- Intelligent driving tuning and test.

3.2. On board integration test

This integration can be done in depot.
Mechanical and Electrical integration and static test (2 or 3 days)

3.2.1. ID mechanical Installation

- Antenna installation
- ID cubicle
- Cabling

3.2.2. Electrical installation/ static check

- Power supply checking : 110 V Battery, AC and 24 V
- Antenna test by moving a beacon under the Antenna
- Traction and Braking interface check one by one
- Odometer input check by slight moving
- Excluder check.

3.2.3. Dynamic check

- Odometer check Running manually at 10 km/h and adjust diameter wheel parameter
- Braking interface check : Test of the 7 level of braking effort
- Motoring check: Test of the 4 level of motoring.
- Antenna check: moving over one beacon put on the track.

3.3. ATO Tuning

ATO tuning aim is to adjust the parameter of ATO to the response of the train.
Two functions are to be tested.
The following procedure is designed to reduce the length of the test track.
The aim of this reduction is to try to allow this phase in depot test track.

3.3.1. Acceleration test

At least 10 runs per target speed (15, 20 and 30 km/h) as follow:

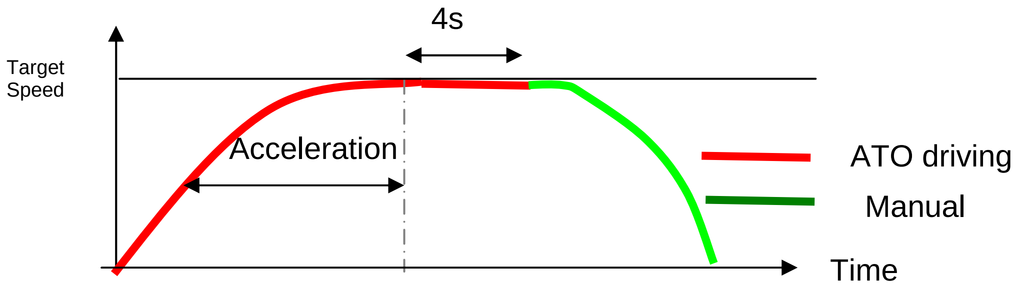


Figure 7. Acceleration test

By target speed the following runs are done:

3.3.1.1. Constant Traction effort , Coasting, Braking

Constant Traction effort, Coasting at target speed, Braking phase
The constant Traction effort asked is a run parameter:
(Low speed, Serial, Parallel, Full)
DIR is drive directly by ID excluder

Traction						
DIR	P1	P2	P3	P4	Coupling	%
1	1	0	0	0	Low Speed	5
1	1	1	0	0	Serial	10
1	1	1	1	0	Parallel	50
1	1	1	1	1	Full	100

3.3.1.2. 2 levels Traction transition, Coasting , Braking

1 run: Traction Serial then Parallel, Coasting at target speed, braking
2 run: Traction Parallel then Serial, Coasting at target speed, braking

3.3.2. Braking test

At least 10 runs per target speed (15, 20 and 30 km/h) as follow:

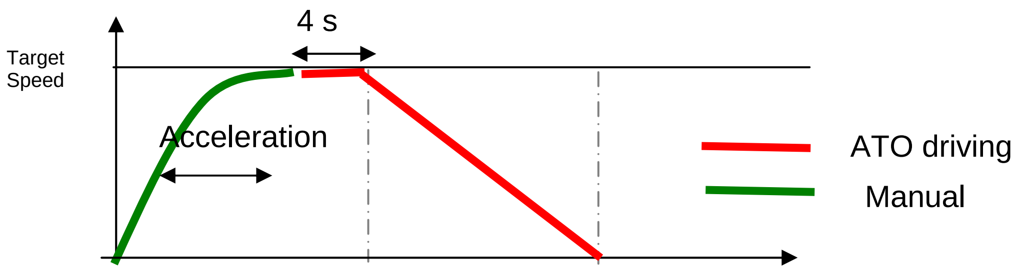


Figure 8. Braking test

By target speed the following runs are done:

3.3.2.1. Traction, Coasting, Constant braking effort

Traction, Coasting at target speed, and then constant braking effort
The constant braking effort asked is a run parameter:
(85 %, 70 %, 60 %, 40 %, 30 %, 20 %)

%	Electrical brake	Pneumatical brake			
Effort	Analog	1	2	3	
100		0	0	0	P7
85	-7,4 V	1	0	0	P6
70	-6,5 V	0	1	0	P5
60	-5,6 V	1	1	0	P4
40	-4,6 V	0	0	1	P3
30	-3,6 V	1	0	1	P2
20	-2,8 V	0	1	1	P1

Nota Bene : Analog value take in account the diode polarization. (- 0,6 V)

3.3.2.2. Traction, Coasting, 2 levels braking effort

1 run: Traction, Coasting at target speed, braking at 40 % and then at 60 %.
2 run: Traction, Coasting at target speed, braking at 60 % and then at 40 %.

Depending of the test result and or availability of test track, the number of target speed or and value of parameter can be reduce.

3.4. Intelligent Driving test

This test must be done on site (see subclause 2.1.1 for precise description of beacon implementation).

If the previous tunings are representative of the tracks conditions, the nominal ATO performance could be check rapidly by 5 runs for each target speed (Checking stopping point accuracy).

For ID tuning, we need 20 to 30 runs for each scenarios of rolling stock degradation.

Each final ID test need 10 to 15 runs.

Depending of the test result and or availability of test track, the number the number of rolling stock degradation scenarios can be reduce.

ID Runs are defined as under:

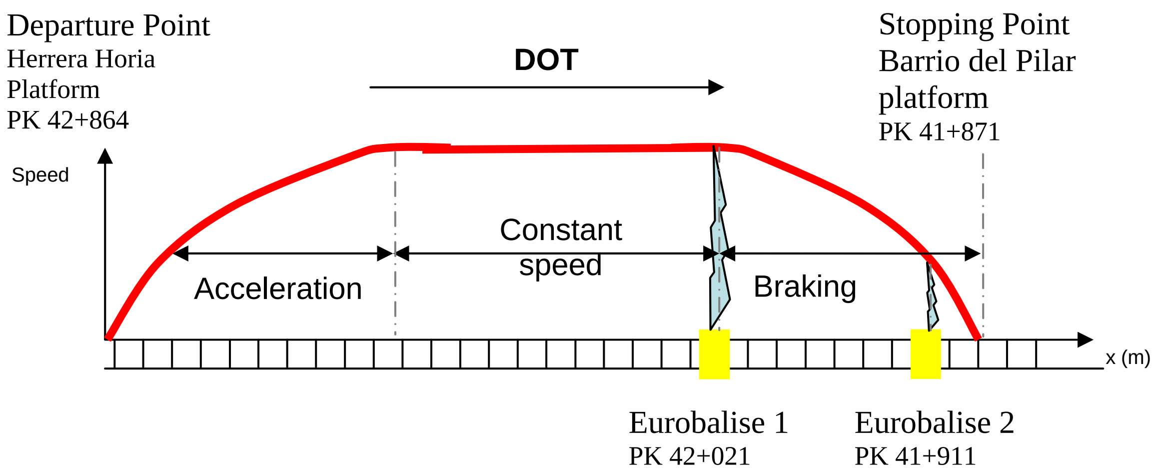


Figure 9. ID test run

4. Tests results

4.1. On board integration test

4.1.1. ID mechanical Installation

Date: 15 - 16th October 2009

- Antenna installation : OK
- ID cubicle : OK
- Cabling: OK

4.1.2. Electrical installation/ static check

→ Date: 15 - 16th October 2009

- Power supply checking : 110 V Battery, AC and 24 V: 0K
- Antenna test by moving a beacon under the Antenna :OK
- Traction and Braking interface check one by one: OK
- Odometer input check by slight moving: OK
- Excluder check : OK

4.1.3. Dynamic check

→ Date: 17- 29 - 30th October 2009

- Odometer check Running manually at 10 km/h and adjust diameter wheel parameter
  - Measured perimeter directly on the wheel: 2,57 m.
  - Implementation of the above parameter in the software: speed compliant.

- Braking interface check : Test of the 7 level of braking effort
  - Changing in the command to send to the train: we have to send the both command (Electrical and Pneumatical) at the same time
  - Verified deceleration

As the maximum deceleration is 1 $m.s^{-2}$ the effort is done in %:

	%	%
	Theoretical Effort	Measured Effort
P7	100	100
P6	85	85
P5	70	75
P4	60	60
P3	40	40
P2	30	20
P1	20	N.A

We decide not to use the P1 level because of his smoothness not of interest for the demonstration.

The in order to obtain the parameter of the train, we compare the results of the different braking tests with a simple model in the Laplace space

$$\frac{1}{1+\tau s}e^{-at}$$

a *delay*
τ *constant time*

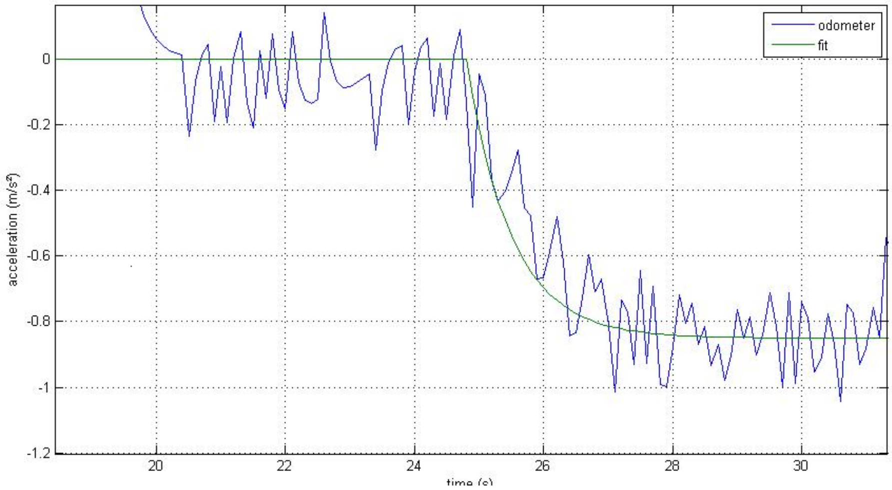


Figure 10. Fit example of a P6 bracking test.

- Motoring check: Test of the 4 level of motoring.
  - Problem with the train interface to motor the train. Problem solved by MetroMadrid
  - Level of motoring OK, driven by software or manually with the relays.

- Antenna check: moving over one beacon put on the track: OK.
- Others:
  - The dynamic tests some changing in the cabling interface with the train occurred. Indeed when the ATO was on it was impossible to the driver to make an emergency brake was. Metro-Madrid managed to by pass the problem for the emergency braking.
  - The cabling of the ATO / Manual driving was also changed by MetroMadrid to allow us to drive automatically the train.

4.2. ATO Tuning

→ Date: 2 – 3 – 4 – 5 – 6 – 9th November 2009

4.2.1. Acceleration test

On the depot test track, the open loop is sufficient to reach the limit speed asked and coast we a slight jerk.

On the line, we decide to take advantage of the slope in order to approximate the behavior of an operating metro. We tuned the motoring ATO to reach a speed around 20 km/h at the beginning of the slope and we command a coasting. So the train accelerates till the bottom of the slope and decelerates on the ramp. Once the train reaches the top of the ramp the tuning of the ATO allow it to reach the first Euro-balise around 20 to 21 km/h.

4.2.2. Braking test

- ATO testing

The first task was to verify if the ATO concept which command the braking phase is valid.

Five runs were dedicated to verify if the breaking phase is correctly triggered by the balises and if the breaking distance fit with the demonstration needs. During those first tests the breaking distance, around 50 to 60 m, was too long. It didn't allow a demonstration set of the ID capability because with a simulated degradation of 10 and 30 % of the braking capability we stop after the platform. The ATO tuning is to smooth

We used some runs to fine tune the ATO's command laws discretization of the braking level and finally obtained a minimal breaking distance around 25 m.

- PID tuning

Then we use a pre-tune PID using the highest constant time drag from the braking level tests and verify that we stop properly. With some minor retuned the minimal breaking distance obtained is around 30 m. We decide to keep this distance has a reference because it allows a good number of runs for the demonstration.

With those tests we can begin to calculate the parameters for the I.D. system.

N.B. During those tests we have pointed out that the parameters of the train are evolving along the night. Despite of that they are quite repeatable during more or less 6 to 8 runs, a sufficient number of test to obtain some results.

4.3. Intelligent Driving test

→ Date: 23 – 25 – 28th November 2009
04 – 12 – 15th December 2009

Test of intelligent driving began by verifying the repeatability of a "nominal" run and if the computed parameters of the train are correct and if the ID is able to absorb the evolution of the train parameters during a night test.

After the dynamic breaking test, we decide to set the nominal breaking distance after the second Euro-balise at 30 m. In this case we can test simulated breaking losses without overrun the platform.

During the first phase of our test, the nominal state we achieved a braking distance of 29,5 m ± 0,3 m

Once it's verified, 5 runs were necessary to verify the repeatability of the simulation of a 30 % braking loss.

In order to be faster during the test we forced the first value of the ID correction. It certainly has saved us around 5 to 10 correction steps (25 to 50 runs). The others runs are made with the I.D. on.

The second phase of the tests was to verify the repeatability of each step of correction for the demonstration.

5. Demonstration

5.1. Demonstration presentation

→ Date: 16th December 2009

The demonstration will take place in December 16th 2008 in Madrid between two stations of the subway line 9. The starting point is Herrera Oria station (starting point) and the arrival Barrio del Pilar.

The Demonstration consists in 10 runs. To demonstrate the intelligent driving capability we choose to show a set of 5 runs, each one played twice. Each runs is triggered by an HMI that also display the results.

5.2. Demonstration HMI

The HMI is divided in four sections:

- Simulation settings (clear blue background, top left),
- data saving (right top),
- data displaying result (bottom left),
- Alarms displaying (dark blue background, bottom right).

Simulation settings: contains 3 buttons: one to launch the simulation one to start the train and the last to stop the simulation and qo the train. The run to be played is set by hand in a box.
Data saving: a box to put the name of the saved file and a drawing button in order to verify the data.
Data displaying result: It's trigged by the passage over the second Euro-balise. It contains a graphical box with the theoretical braking phase of each demonstrated runs. It also indicates numerical values of the speed and the braking distance after the second Euro-balise.
Alarms displaying: Under or Over braking lighten in red if detected, ID lighten in Green if in action or Normal State lighten in green if the braking is normal.

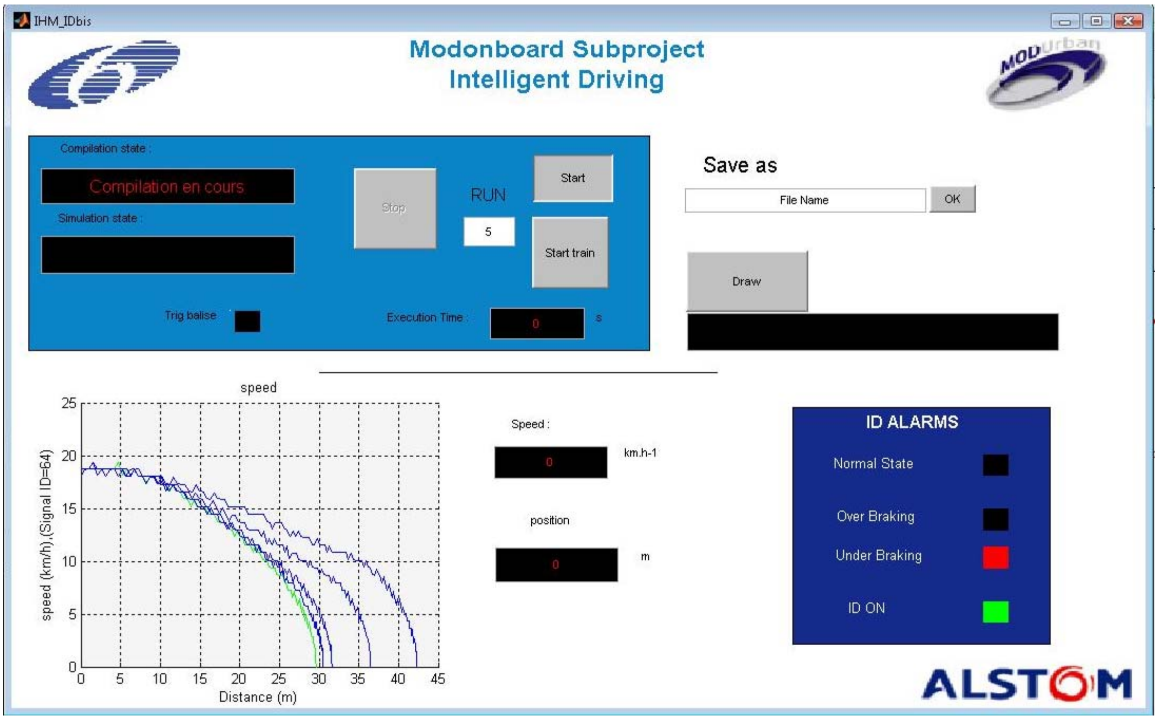


Figure 11. HMI presentation

5.3. Demonstration Scenario

The demonstration consists in a set of five run played twice.

- The first one simulates a 30 % loss of braking capability,
- The 3 following runs will present a stage of I.D correction;
- The fifth one will be the return to the nominal state (with ID on).

The train is automatically driven from Herrera Oria to Barrio del Pilar. The train reaches a maximum speed around 50 km/h at the middle of the run and the ATO makes it reach the second Euro-balise at a speed around 20 to 21 km/h. It brakes and we put marks on the floor to show the ID effect. After that the train is driven manually to the starting station.

The sequence played will be:

- 2 run 1: Braking loss of 30 %
- 2 run 2: First step of ID
- 2 run 3: Second step of ID
- 2 run 4: Third step of ID
- 2 run 5: last step of ID with return to nominal state.

Theoretical nominal breaking distances from the second balises :
(Nominal State) NS = 29,6 m ± 0,4 m

- run 1: NS + 12,7 m ± 0,4 m
- run 2: NS + 9,6 m ± 0,4 m
- run 3: NS + 2 m ± 0,4 m
- run 4: NS + 0,9 m ± 0,4 m
- run 5: NS + 0 m ± 0,4 m <- Nominal state of the braking

The HMI only displays the breaking phase after the second Euro-balise to make it possible to see the difference between the different braking distance.

5.4. Demonstration results

A nominal run is a run with a breaking distance accuracy comprises in the 40 cm of repeatability obtains during the tests.

- Run1
  - First one: Not nominal NS + 35 m (cold brake)
  - Second one: Nominal NS + 12,4 m
- Run2
  - First one: Nominal NS + 10 m
  - Second one: Nominal NS + 9,6 m
- Run3
  - First one: Nominal NS + 2,2 m
  - Second one: Not Nominal NS + 4,5 m (No explanation)
- Run4
  - First one: Nominal NS + 1,1 m
  - Second one: not played
- Run5
  - First one Not Nominal NS - 1,5 m
  - Second one: not played