D2.3 Identification of the Representative Railway Lines / Sites

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1 INTRODUCTION

1.1 EXECUTIVE SUMMARY

The purpose of this document is to provide a description of the selected lines and railways sites with the possible test vehicles on which to proceed the preparation of the measurement campaign planned in the context of STARS WP3. The definition of the criteria to select the lines and railways sites has also been included here from what has been carried out and reviewed in the TN [5] dedicated to this task. This deliverable is related to task 2.3 defined at the WP2 project planning. It should be taken into consideration that the decisions taken in WP2 are strongly linked to the subsequent development of WP3.

1.2 DEFINITIONS AND ACRONYMS

Acronym	Meaning
1D	One Dimensional
3D	Three Dimensional
ATP	Automatic Train Operation
DOP	Dilution Of Precision
DCF77	German longwave time signal
EGNOS	European Geostationary Navigation Overlay System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IMU	Inertial Measurement Unit
MIB	Magnetic Information Balise
NLOS	None Line Of Sight
PVT	Position Velocity Time
RTK	Real Time Kinetic
SBAS	Satellite Based Augmentation System
SV	Space Vehicle

2 REQUIREMENTS FOR SELECTING TRACK AND TRAIN

Selecting diverse test tracks and vehicles is very important for the STARS test campaign, as the performance of GNSS shall be evaluated in different environments.

This chapter discusses the characteristics of possible tracks and vehicles and how suitable they are to achieve the goals of STARS.

2.1 DIVERSE ENVIRONMENTS

The data collected during the STARS measurement campaign shall be collected in different environments, representing all possible operational scenarios. The following lines should be covered, but should not be limited to:

- High speed lines
- Topographically difficult lines (valleys, tunnels, forests)
- Urban lines

These types of lines can be characterized by different types of environment:

2.1.1 Open Sky Environment

An open sky environment is characterised by good satellite visibility if the total number of GNSS satellites in view (mainly GPS and Galileo SVs but also GLONASS SVs...) which are appropriate for PVT computation are more than a minimum number for PVT computation. Moreover, an open sky environment is characterized by good satellite visibility if the overall geometry of the various GNSS satellites with respect to the user receiver results in a low DOP. These two conditions should be satisfied continuously with rare interruptions. Moreover, an open sky environment also provides good SBAS (mainly EGNOS in Europe) satellite visibility in terms of line of sight reception, with rare and limited reduction of satellite visibility (Figure 1).

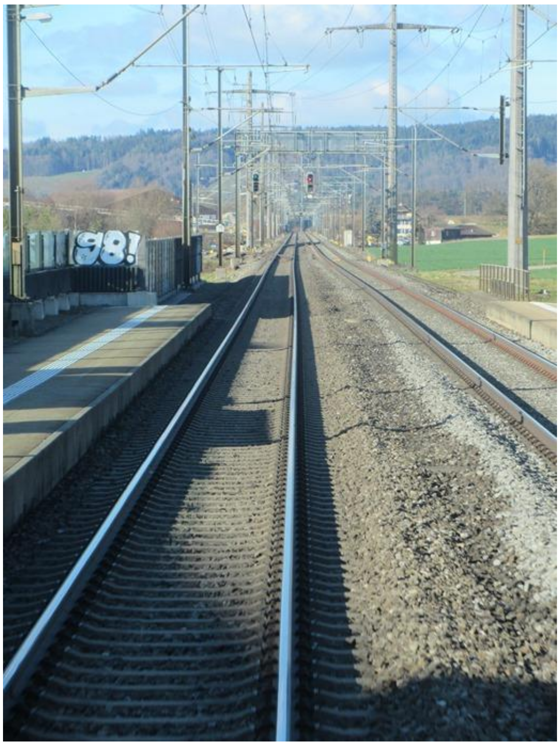

Figure 1: Example of Open Environment

2.1.2 Restricted Environment

A restricted environment is characterised by frequent interruptions of satellite visibility, and a significant reduction of the number of available GNSS satellites (mainly GPS and Galileo but also GLONASS…) for PVT computation and consequently a large value of the DOP. A restricted environment is also characterized by a continuously changing visibility of individual satellites and GNSS signal multiple reflections (multipath) or also with no direct reception of the satellite signal (NLOS No Line Of Sight reception).

In a restricted environment, SBAS (EGNOS in Europe) satellites might only be visible sporadically.

Typical restricted areas are mountainous areas or areas with frequent tunnels and cuttings, such as high speed lines (Figure 2).

Figure 2: Example of restricted environment

2.1.3 Urban Environment

An urban environment is characterised by frequent interruptions of satellite visibility, with the number of available GNSS satellites (mainly GPS and Galileo but also GLONASS…) for PVT computation significantly reduced, and a continuous changing visibility of individual satellites and consequently a continuously changing DOP value greater than a minimum number. This is combined with high probability of multipath and NLOS phenomena affecting GNSS signals, largely due to reflections and obstructions created by surrounding buildings.

In an urban environment, SBAS (EGNOS in Europe) satellites might only be visible sporadically.

Typical urban areas are inner city lines, and an example of an urban environment is shown in Figure 3.

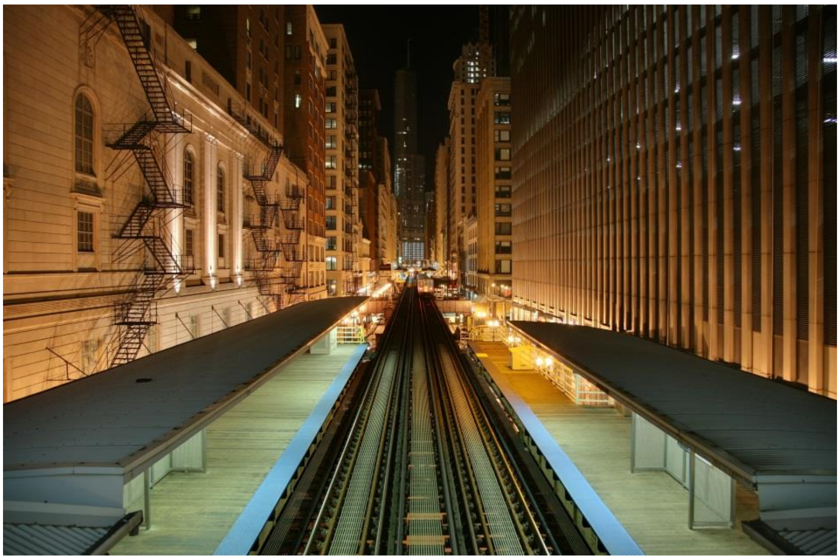

Figure 3: Example of urban environment

2.2 GEOGRAPHIC TRACK DATA

Geographic track data corresponds to data coming from railway line specification in terms of all geographical information including if applicable Eurobalises, geographical RFID tags, tunnels, bridges, and possible obstacles should be covered:

- Presence of high/low buildings
- Presence of natural obstacles
  - Mountains
  - Valleys
  - Trees
  - Others
- Presence of man built obstacles
  - Tunnels
  - Electrified lines
  - Roofs on a station
  - Others
- Others

Before the initiation of any test measurement campaign, an analysis of the tested line should be performed. An updated map of the line should be used for the identification of any obstacles within the line. All these obstacles should be noted and characterised. The following information on track data could be useful and is recommended to be expressed in Cartesian coordinates under the WGS84 reference frame (be aware of the shift in time of the coordinates expressed in these reference frames. The Euro-Asian continent moves approximately 3cm/year in this reference frame):

- GPS position of the obstacles, width, height and distance to the track.
- Kilometric point within the line.

2.2.1 Availability

The availability of digital track data provides a good advantage in order to analyse the data collected during the measurement campaign, as the measured data and subsequently the calculated train position needs to be compared to an absolute reference. However, this sort of track data should be dealt with care as there are several aspects to consider:

- the digital track data of a railway line is available with different accuracy levels as a function of the kind of line in consideration and the different points of the line
- the digital track data can be outdated due to the continuous movement of the European continent, and as such, it is important to request from railway line operators, specific information on:
    - the date of the survey which has been conducted
    - the nature of the measurement system used to produce the digital track data
    - the digital track data accuracy level
    - the reference system in which the position coordinates are expressed and how to transform from the used reference system to the global WGS84 reference system used by GPS

Access to track database can be not so straightforward, but apart from that it is important to identify the kind of data necessary to satisfy different purposes. Track database can be expressed in terms of:

- track axis position in 3D coordinates
- track parameters (e.g. the cant of a track)
- pictures of track clearance profile (i.e. track and its surrounding terrain)
- etc.

To avoid confusion, it is important to make a distinction between digital track data which is static information of the railway line with no timestamp and the ground truth which is a time stamped position information relative to a running train. Indeed, the track data content can be a geo-referenced survey of the track line with cm level accuracy and an a-priori sampling of the order of meters, whereas the ground truth data content can be the train position on the track line in 3D coordinates associated to a time stamp relative to the traveling train clock, which can be directly related to UTC time reference or GPS time.

In any case, a comparison of the digital track data and the train position computed using GNSS signals is not straightforward as the digital track data information is relative to static conditions and needs to be timestamped to provide a true reference for train position computation. However, the availability of digital track data will be useful to project the estimated position on a 1D curvilinear line and deduce the cross track error.

As an example, the following figures (Figure 4) show the availability of track data for the railway network of DB AG. The left figure shows the availability of track data from the free OpenDataPortal from DB AG and the right figure shows the lines for which more detailed data is available.

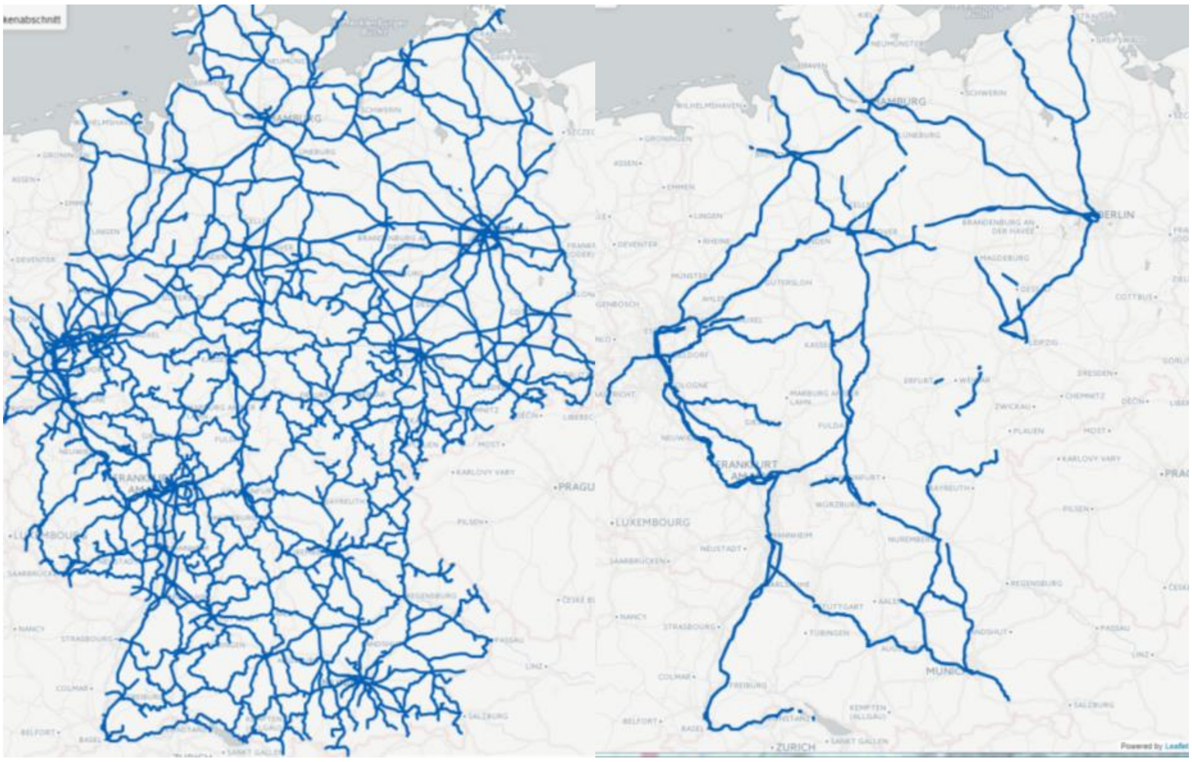

Figure 4: Data availability, left: OpenDataPortal, right: DB AG main line track data

2.2.2 Track selective data

Figure 5 shows two examples showing the data points from the two aforementioned sources: OpenDataPortal and DB AG. The open data portal only provides one track data point for both tracks of double track lines, as shown in the left figure, whereas the more detailed data from the track data base shown in the right figure contains separate data points for both tracks. In order to correctly evaluate position errors caused by local effects (multipath, NLOS, interference etc.) and perform track discrimination, the track selective data is an important point. This question is strongly related to track point accuracy described in the next section.

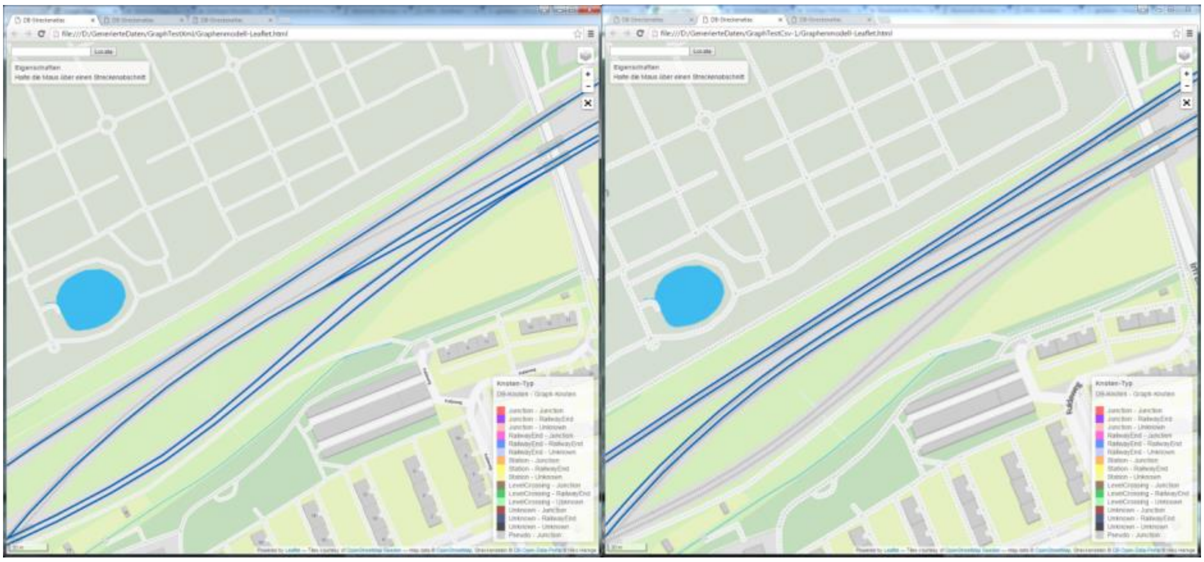

Figure 5: left: OpenDataPortal, right: DB AG main line track data

2.2.3 Accuracy and validation of track data points

It is obviously also important to take into consideration the accuracy and confidence level of the provided data points, and whether the provided track data is validated. In general, different validation methods can be used and it is not straightforward, however due to timing and budget constraints the track database validation is not to be considered in the scope of this project. As previously stated, the track data points information should be dealt with attention as there is no guarantee on the accuracy of this type of information for several reasons mentioned in the previous section. In fact, it is hardly possible to do validation of measurements with cm resolution without a static procedure like a line survey. A line survey has been performed in most of the trial sites we have considered. When this is not the case, the analysis of the Ground Truth measurements as compared to GNSS measurements shall consider that some track database or reference points are not validated and can incur precision errors on their own.

In fact, the track position data accuracy will differ according to the kind of railway line in consideration. In case of older regional lines which are the most suitable for the tests from environment diversity viewpoint, the expectation to obtain accurate data is pessimistic. There are several reasons for this: the track construction does not fully correspond to the project plan of the track in the past, where the additional geometry changes have been caused by wearing of the track or by maintenance of track superstructure.

In such cases where digital track position data accuracy is subject to scepticism, it is possible to adopt different ground truth techniques (see [3] and [4]) which yield different accuracy levels to provide a reference position and even to check track data matching. In fact, the ground truth information that is computed during several train runs on the same line can be used to assess and verify track database information for open sky environments after confronting with geographic track data as defined in section 2.2. Camera use is also a possibility to discriminate between tracks.

For example, one ground truth measurement technique is the use of IMU complemented GNSS RTK measurements. Recently performed measurements on one of the regional lines located in South Bohemia have provided information on availability of RTK measurement. There were executed four test runs during one day to have different constellations and the results are very promising - only several track sections not exceeding a length of 500m were identified to have missing RTK measurements within a track of 60km length (see Figure 6).

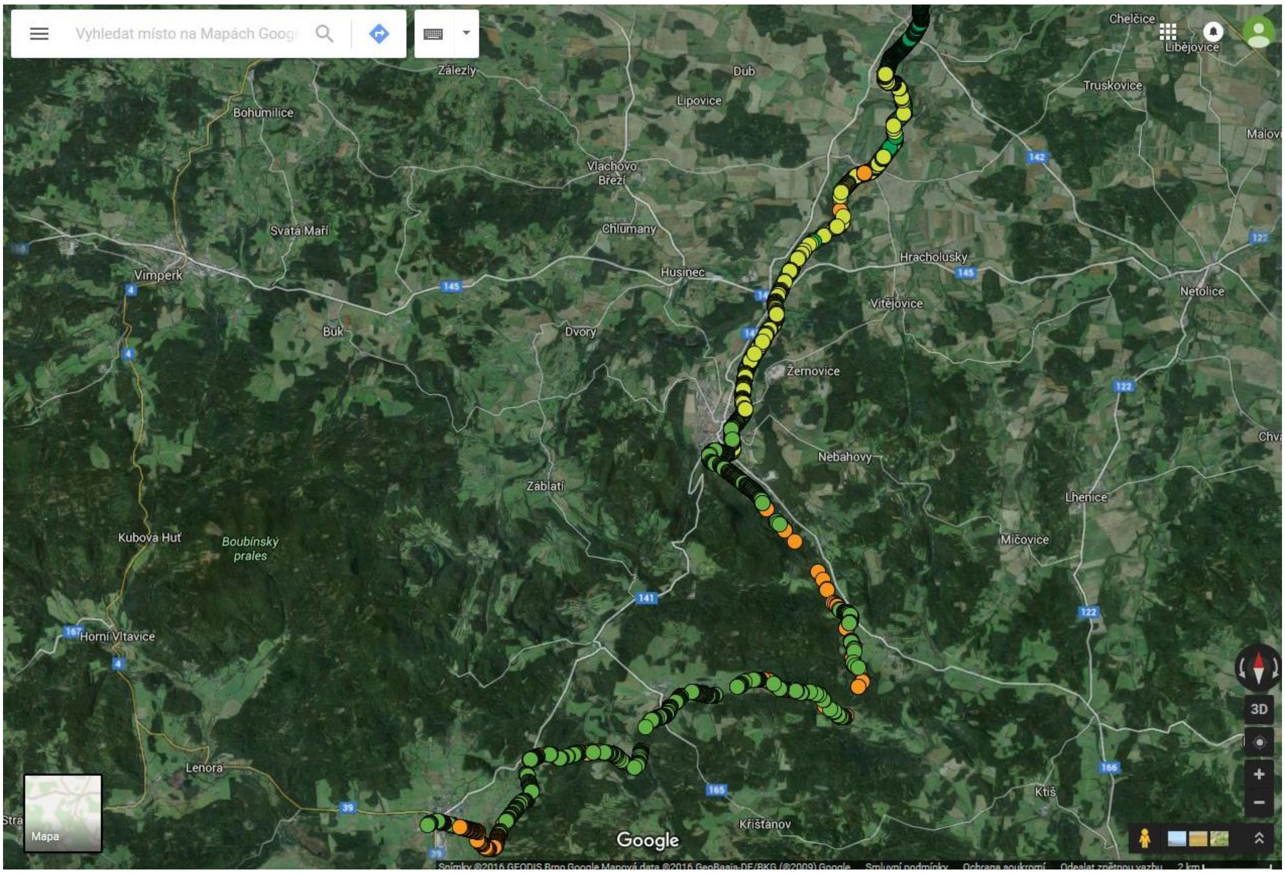

Figure 6: GPS RTK availability on regional line in South Bohemia

2.3 REFERENCE POINTS

During GNSS performance assessment measurement campaign, it is also important to use some reference points which provide geolocation info, such as beacons, which can be detected with high level of accuracy even if the use of GNSS is not reliable or is subject of discussion (e.g. a high density foliage area or tall and narrow buildings environment). This will help assessing the true GNSS performance at controversial points by comparing it to an independent and reliable measurement system. It is important to have such reference points available at critical points identified along the line (as described in section 2.2), preferably with a unique identification method to simplify data analysis. They need to be distributed across all railway lines where measurements are being performed. Below, some examples are listed; however they only represent possible solutions for reference points.

An example of a unique reference point is the Eurobalise (Figure 7), which can be detected with a balise reader installed on the test train.

Note that reference points can be used to calibrate odometer or other distance/speed sensors. These sensors can be used in different ways when it comes to GNSS performance assessment:

- to complement GNSS when it is available or not,
- to provide an independent measurement system

It is interesting to note that the use of reference points for GNSS performance assessment is reasonable when either the use of GNSS is reliable or subject of discussion. In fact, for the aforementioned purpose, it will not make sense to have reference points, where GNSS will never be used (such as in a tunnel).

Figure 7: Eurobalises

An example of a non-unique reference points is the *Indusi* magnet Figure 8, some of which can be detected only if certain signal aspects are shown. Again an *Indusi* reader is needed on-board the train to detect the magnets. Some form of post processing is needed to match detected *Indusi* magnets to absolute positions and detection time.

Figure 8: Indusi magnet

As an alternative, a camera in the driver's cab could be used to record the train position, significant post processing will however be needed to match the recorded data to absolute train positions and time with high accuracy, for example by using the absolute position of track kilometre marker boards or catenary poles (Figure 9). The position of marker boards should also be validated, possibly using data collected during the measurement campaign (relative speed/distance measurements, wheel tachometer), or by checking with the rail operators the accuracy of the reference points.

Figure 9: Track kilometre marker board / catenary pole

2.4 VEHICLE SPECIFIC CRITERIA

2.4.1 Engine Type

The use of vehicles with different engine type will enable comparison of measured data and evaluation of influence of traction system on GNSS performance. A critical influence on the GNSS signal could result from electromagnetic interference generated by the traction system, such as from electric arcing which occurs between the pantograph (Figure 11) and the catenary wire in the case of AC/DC Electric Trains. This becomes amplified with frosty rime at the wire. It will be experimented whether the EMI due to electric arcing depends on the antenna placement with respect to the pantograph. Based on AŽD experience in the past,

- the pantograph negatively affects positioning based on carrier phase measurement in the case antenna is in pantograph vicinity (cycle slips happen very often)

– no influence of electric arcing was observed during positioning based on carrier phase measurements performed in winter several years ago (under frosty rime conditions) in the case antennas are not located in pantograph vicinity (see Figure 10).

It is useful to clarify with the train operators their flexibility in authorizing multiple antenna installations to check the EMI effect due to electric arcing.

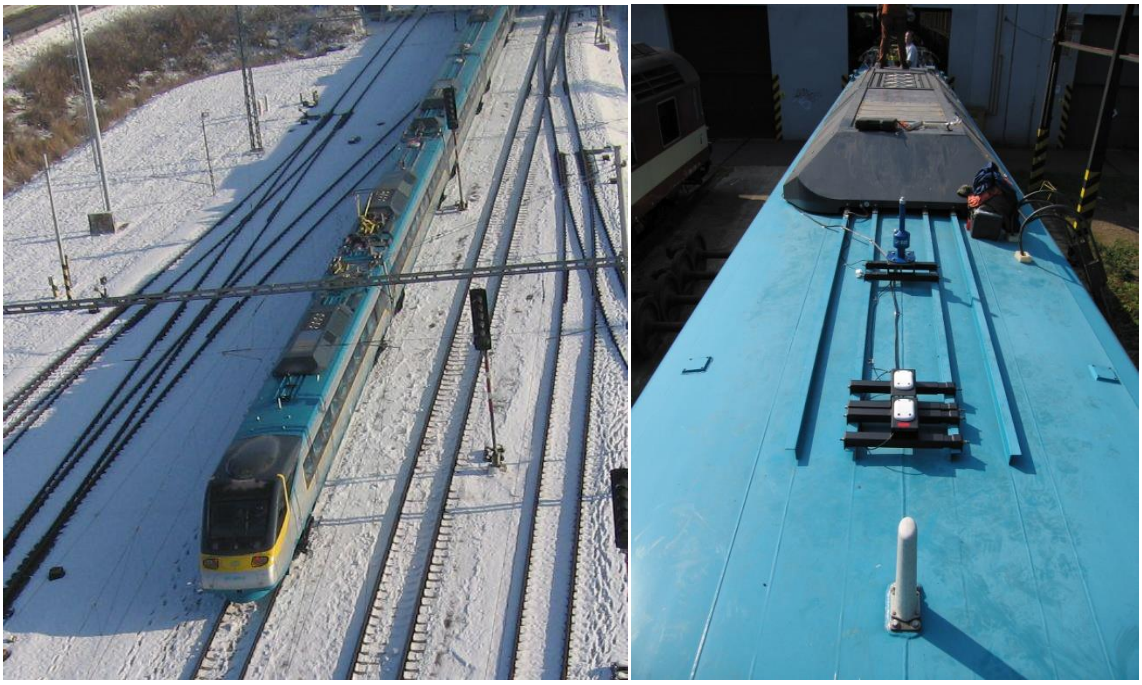

Figure 10: GNSS antennas location on the roof of vehicles of 680 series

The possible engine types for electric trains are:

1. 750Vdc
2. 1500Vdc
3. 3000Vdc
4. 15000Vac
5. 25000Vac

Figure 11: Pantograph of electrical powered vehicles

Concerning diesel engine vehicles the electrical generator can be a potential source of the electromagnetic interference.

It is evident that location of GNSS antenna and receivers on vehicle is also important and installation conditions should be discussed and recommendations for installation should be specified. But this will not usable in the case of multisystem vehicles (locomotives with several pantographs) where only very limited place for antenna installation is available.

2.4.2 Maximum vehicle speed

GNSS performance depends on the speed of a vehicle, it could therefore be important to perform measurements over a high speed range. For high speed vehicles pantograph bouncing and arc generation should be assessed. In this sense interfering signals could be generated in the pantograph-line contact and the impact of this type of interference on GNSS should be assessed. On the other hand, speed-dependent phenomenon with negative impact on GNSS performance arises with sudden change of constellation in view, but not only. Sudden change of GNSS constellation in view will depend mainly on the track surrounding environment and receiver capabilities, i.e. the time to acquire GNSS signal and to provide solution. In fact, higher speed results in faster passage around obstacles and enables receiver to continue track signal. Moreover vehicle movement mitigates multipath influence on position error so from the viewpoint of multipath low speeds are much more critical.

Testing on both low and high speed vehicles could therefore be important.

Figure 12: High speed train

Figure 13: Regional train

2.4.3 Installation and maintenance

The installation of the test equipment should be performed by the owner of the test equipment or the subcontractor in charge of the testing campaign (the agent responsible for the test equipment) unless otherwise agreed. It is therefore important that the respective organisation is available to perform this work. Any work on the vehicle is to be overviewed by the maintenance company which should guide/help/assess about the equipment installation.

2.4.4 Test execution and data collection

Due to the long duration of the test campaign it will be of big advantage if measurements could be automated. To download the data from the train it will either be necessary that the train is parked where a remote download is possible, or where maintenance staff could download the data manually, e.g. by swapping disks. It is also necessary to be aware of automated measurement limitation due to operating temperature range of installed devices. Replay Playback System or Vector Spectra Analyser are not usually designed to work in the range of low temperatures.

2.4.5 Approval procedure

As any change to a train requires some form of approval and as this can be complex and time consuming it will be important to minimize the need for approvals. This could vary from simple inspection of constructional drawings and installation at the train with conclusive acceptance by the vehicle operator, up to advice of change of vehicle construction at the local authorities. It will therefore be important to get support from the installer to obtain necessary approvals as efficiently as possible, as well as from local authorities to minimize approval requirements. Using a test vehicle which is not used in commercial service might be an important factor too.

3 SELECTION CRITERIA

The following table contains a number of criteria relevant to select optimum test vehicles and tracks. Note that not all test sites will fulfil all criteria, it should however be ensured that all criteria are covered and distributed among the different sites on which the measurement campaign will be carried out. Some criteria are however of very high relevance, as the execution of the campaign would be difficult if they are not fulfilled.

Criteria	Applicability	Characteristic	Relevance	Description
Track type diversity	Track	mountainous tracks, secondary lines, urban tracks, high speed lines and others	High	
Environment diversity	Track	Open sky, restricted and urban environment	High	
Operated track	Track	Length	Low	It should be ensured that the track used is sufficiently long to provide diversity, and to avoid that measurements are only performed in an area which might be uniformly impacted by a single parameter
Geographical track data	Track	Availability, accuracy	Low to High (depends on the available Ground Truth measurement system capability)	Data analysis will depend heavily on accurate ground truth information and digital track data; although a good ground truth measurement system can make track data information obsolete. The absolute train position reference will have to be compared with the position determined by GNSS. Track data must be track selective, providing separate data for each track on a line. Note: If track data first needs to be generated this will be prohibitive for cost and schedule reasons, unless it is limited to short sections of track.
Reference points	Track	Availability	High	Same as above, reference points will be required to provide frequent absolute position information. If

Criteria	Applicability	Characteristic	Relevance	Description
				reference points can also provide identity information the analysis will be simplified, if not some manual post processing will be required. Note: If reference points need to be installed first this will be prohibitive for cost and schedule reasons, unless it is limited to short sections of track.
Reference points reading device	Train	Availability	High	Depending on the type of reference points used an appropriate device is needed to detect them. It might be possible to access this information from an already present device (e.g. Eurobalise reader of ATP system), alternatively a separate reader could be installed.
Traction system	Track and train	Type	Medium	Electric traction generates significant electromagnetic interference, which might interfere with GNSS reception.
Maximum speed	Track and train	Broad speed range	Low	GNSS performance in certain environments is speed dependent; it is therefore of advantage if measurements can be performed in a range of speeds also covering very high speed.
Odometry information	Train	Availability, accuracy	Medium	Data analysis will depend heavily on accurate odometry (accelerometer) information between reference points, as the absolute train position will have to be compared with the position determined by GNSS. Note: If no odometry information is available a separate odometry system will have to be installed.

Criteria	Applicability	Characteristic	Relevance	Description
Approval	Track and train	Required effort	High	Complexity and effort for approval of test installations differs significantly from country to country
Installation / maintenance	Train	Cost	High	The cost of the installation of equipment on board the train must be reasonable to fit into our budget.
		Availability	High	Installation must be possible within the timeframe of task 3.2
Installation space	Train	Availability	High	Sufficient space must be available on board the train for equipment
Test runs	Track and train	Frequency	Very high	Test runs must be scheduled frequently for reasons outside STARS, as the budget does not allow for test runs financed by the STARS project
Data download	Train	Availability	Very low	Remote access of data should be available or if no download possibility exists a manual downloading procedure must be carried out

Table 1: Railway lines selection criteria

4 POSSIBLE TEST SITES AND VEHICLES

During the proposal phase of the project it was decided to use test sites in three countries, each one of which is managed by AZD, Ansaldo STS and Siemens. This is also reflected in the project planning and budget. It will therefore be necessary to select test sites and vehicles in the Czech Republic, in Italy and in Germany/Switzerland. The selection of the test sites and vehicles shall be coordinated to ensure that the selection criteria defined in [5] are satisfied.

4.1 ITALY TEST SITES

There are at least two main lines in Italy that satisfy the criteria defined in [5]. The Pontremolese line between Parma and La Spezia, and the Cagliari – San Gavino section (part of the Cagliari – Sassari line) in Sardinia. The two test sites present different environmental conditions and accept different vehicle types. The Pontremolese line presents challenging conditions in terms of obscuration (bridges and tunnels…) and accepts electric locomotives whereas the Cagliari – San Gavino section mostly presents open sky conditions and accepts Diesel engines.

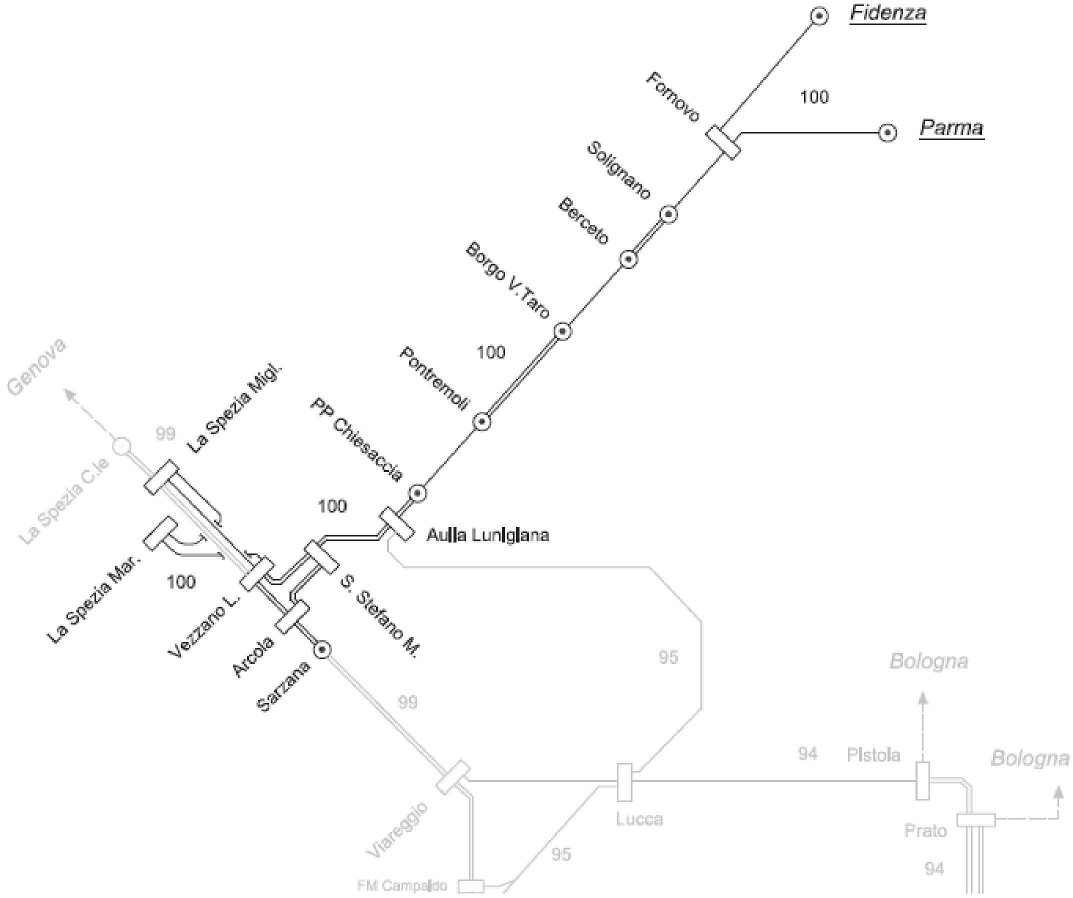

Figure 14: Pontremolese line

Figure 15: Sardinia line between Cagliari and San Gavino

4.1.1 Vehicle Ale642 running on Pontremolese line

Figure 16: Ale642 and Le682 locomotives rooftop structure

Category	Description	Rating
Vehicle type	Ale642	-
Operator	Trenitalia	-
Address	Piazza della Croce Rossa, 1 - 00161 Roma	-
Contact Person	To be finalized	-
Track type	Commercial trains running on regional railways with valleys, tunnels, overpasses, woods	High
Size of used railway net	119 km total distance from Parma to La Spezia	High
Geographic track data	The survey has been performed by a certified company "Durazzani srl"	High
Accuracy of geographic track data	All the objects of the line are provided in GPS coordinates and the entire track from Parma to La Spezia has been surveyed.	High
Validation of track data	The GPS data has been collected with RTK method by a certified company and a database and a DWG format with all the relevant information is available in terms of accuracy in cm	High
Reference points	**Balises**, Joints, Level crossing, Track kilometre marker boards, Bumpers, Axle counters, Switch points, Signals, Border markers	High

Category	Description	Rating
Number of reference points	**1128 Balises (564 BGs)** 535 Joints 56 Level crossing 93 Track kilometre marker boards 37 Bumpers 50 Axel counters 535 Switch points 225 Signals 419 Border markers	High
Position of reference points	All along the line	High
Track chainage	Available	High
Engine type:	Electric	High
Max. speed:	140 km/h	High
Quality of speed reference	2% (as per Trenitalia ST 372574)	High
Speed reference	Wheel tachometer available	High
Approval	Approval of current installation: Trenitalia TRNIT-DT IRTB\P\2013\0019149	High
Costs	minimal due to use of vehicle during normal passenger operation, excluding equipment installation	-
Next installation date:	as soon as installation equipment is ready	-
How often are test runs scheduled?	No test runs, trains run on the basis of commercial schedule (6 times a day on average).	High
Reference time on board available	GPS and Odometric Time	High
Installation space	500x450 mm cabinet used for GNSS receivers, and other equipment	-
Data download in depot	possible	High

4.1.2 Vehicle ALN668 – 3114 running on Sardinia line between Cagliari - San Gavino

Figure 17: Locomotive and on-board installed antennas and cables

Category	Description	Rating
Vehicle type	ALN668 – 3114	-
Operator	Trenitalia	-
Address	Piazza della Croce Rossa, 1 - 00161 Roma	-
Contact Person	To be finalized	-
Track type	Commercial trains running on regional railways with valleys and overpasses	High

Category	Description	Rating
Size of used railway net	50 km total distance from Cagliari to San Gavino	High
Geographic track data	The survey has been performed by a certified company "Durazzani srl"	High
Accuracy of geographic track data	All the objects of the line are provided in GPS coordinates and the entire track from Cagliari to San Gavino has been surveyed.	High
Validation of track data	The GPS data has been collected with RTK method by a certified company and a database and a DWG format with all the relevant information is available in terms of accuracy in cm	High
Reference points	(Balises), Joints, Bumpers, Switch points, Marker Boards	High
Number of reference points	(262 Balises) (131 BGs) 292 Joints (2 Level crossings) 24 Bumpers (241 Track circuits) 101 Switch points (101 Signals) 119 Marker boards	High
Position of reference points	All along the line	High
Track chainage	Available	High
Engine type:	Diesel	-
Max. speed:	130 km/h	High
Quality of speed reference	2% (as per Trenitalia ST 372574)	High
Speed reference	Wheel tachometer available	High
Approval	Approval of current installation: Trenitalia TRNIT-DT IRTB\P\2015\0036020	High
Costs	minimal due to use of vehicle during normal passenger operation, excluding equipment installation	-
Next installation date:	as soon as installation equipment is ready	-

Category	Description	Rating
How often are test runs scheduled?	No test runs, trains run on the basis of commercial schedule. Two to three roundtrips a day.	High
Reference time on board available	GPS and Odometric Time	High
Installation space	3000 x 1100 mm cabinet used for GNSS receivers and other equipment	High
Data download in depot	Possible, not only in depot but at the end of each train run	High

4.2 SWITZERLAND TEST SITES AND VEHICLES

4.2.1 RBDe 560 Trains

Figure 18: RBDe 560 Train

Parameter	Description	Rating
Vehicle type	RBDe 560	-
Operator	Schweizerische Bundesbahnen SBB, Personenverkehr	-
Address	Brückfeldstrasse 16, 3000 Bern 65, Switzerland	-
Contact Person	All contacts towards SBB via Bernhard Stamm, Siemens Schweiz AG, Hammerweg 1, 9506 Wallisellen, Switzerland	-
Track type	Main- and regional lines on SBB network, including mountainous and urban sections	High

Parameter	Description	Rating
Operating network	SBB Infrastructure	High
Geographic track data	Available from SBB infrastructure	High
Accuracy of geographic track data	cm	High
Validation of track data	Available from SBB	High
Reference points	Eurobalises	High
Number of reference points	More than 50’000 on 3000 km of routes	High
Position of reference points	Irregular, at least approximately every 1’000 m, many more in stations. One balise pair at each signal, as well as additional ones in the approach to signals.	High
Track chainage	Available	High
Engine type:	Electric powered regional train, 15 kV, 16.7 Hz	-
Max. speed:	140 km/h	High
Quality of speed reference	Good	High
Speed reference	Raw data from radars, wheel tachos and ETCS reference speed, CorRail sensor planned	High
Approval	Approval for on board installation in progress already, due to parallel use of the vehicle for ETCS testing, with only additional GNSS antenna and possibly sky camera required.	High
Costs	Minimal due to parallel use of the vehicle for ETCS testing and testing during normal passenger operation. If specific test runs are required this might cost around 4’000 € per day.	High
Next installation date:	Installation to take place in August 2016	High
How often are test runs scheduled?	Measurements can be done during normal operation on a daily basis, specific test runs to be scheduled but not considered necessary.	High

Parameter	Description	Rating
Reference time on board available	GPS (GPS receiver independent from STARS installation)	High
Specials:	Vehicle also used for ETCS testing, measurements can be done on a daily basis during normal passenger runs, train operates according to timetable. Measurements can be accompanied, as equipment is installed in unused baggage compartment.	High
	Train normally operates in a certain area of the network, but might be moved between areas as a larger number of the type is operated across the country.	High
Installation space	Sufficient space for test equipment and staff in unused baggage compartment	High
Data download in depot	Via exchange of hard disks, upgrade to WLAN planned, UMTS also possible depending on data volume.	High

Figure 19: GNSS Antenna Installation

Figure 19 shows the minimum/common GNSS antenna selected for the STARS measurement campaign installed at the SBB train.

As it has been mentioned in above table, the SBB trains run in normal operation in main and regional lines. In the following figure an overview of the SBB lines is included (source: www.sbb.ch)

Figure 20: SBB regional and main lines overview

4.3 CZECH REPUBLIC TEST SITES AND VEHICLES

4.3.1 Electrical Locomotive 362 WTB

Figure 21: Electrical locomotive 362 WTB

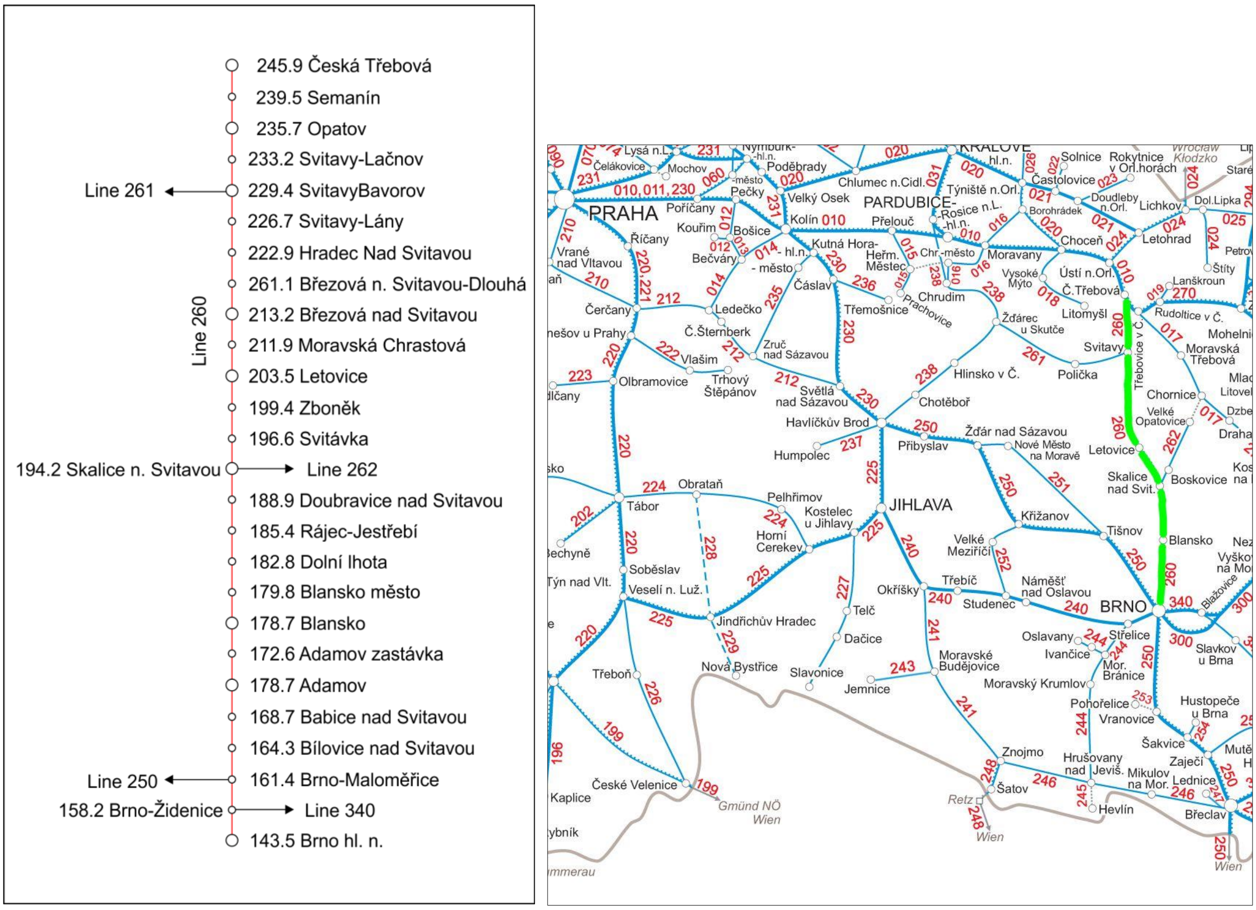

Figure 22: Test track operated by 362 WTB

Category	Description	Rating
Vehicle type	362 WTB	-
Operator	Czech Railways	-
Address	Nábřeží Ludvíka Svobody 1222, 110 15 Praha	-
Contact Person	ing. J. Konečný phone: +420972233870 e-mail: konecnyj@gr.cd.cz	-
Track type	Commercial train running on corridor line with valleys, tunnels, overpasses, woods	High
Size of used railway net	102 km total distance from Česká Třebová to Brno hl.n.	High
Geographic track data	The survey has been performed by Czech Railway Administrator (SŽDC) – Railway Geodesy Department	High
Accuracy of geographic track data	All the objects of the line are provided in WGS-84 coordinates and the entire track from Česká Třebová to Brno hl. n. has been surveyed.	High
Validation of track data	Checked by SŽDC track measuring car at interval of twice a year or after each maintenance.	?

Category	Description	Rating
Reference points	**Magnetic Information Balises (MIB)**, Level crossing, Speed indicator boards, Switch points, Poles, Signals	High
Number of reference points	**408 MIBs**	High
Position of reference points	All along the line	High
Track chainage	Available	High
Engine type:	Electrical DC 3kV + AC 25kV/50Hz	-
Max. speed:	140km/h	High
Quality of speed reference	<1%	High
Speed reference	Wheel tachometer	High
Approval	Installation has to be approved by Rail Authority in Czech Republic	High
Costs	Equip of vehicle and maintenance of measurement system: 15K €	High
Next installation date:	After approval of installation design, within any service inspection in depot	High
How often are test runs scheduled?	Daily operating train	High
Reference time on board available	DCF77 Time	High
Installation space	Free space in engine room is available for installation of equipment	High
Data download in depot	Possible, not only in depot but at the end of each train run	High

4.3.2 Diesel Multiple Unit 814-914 (Regionova)

Figure 23: Diesel Multiple Unit 814-914 Regionova

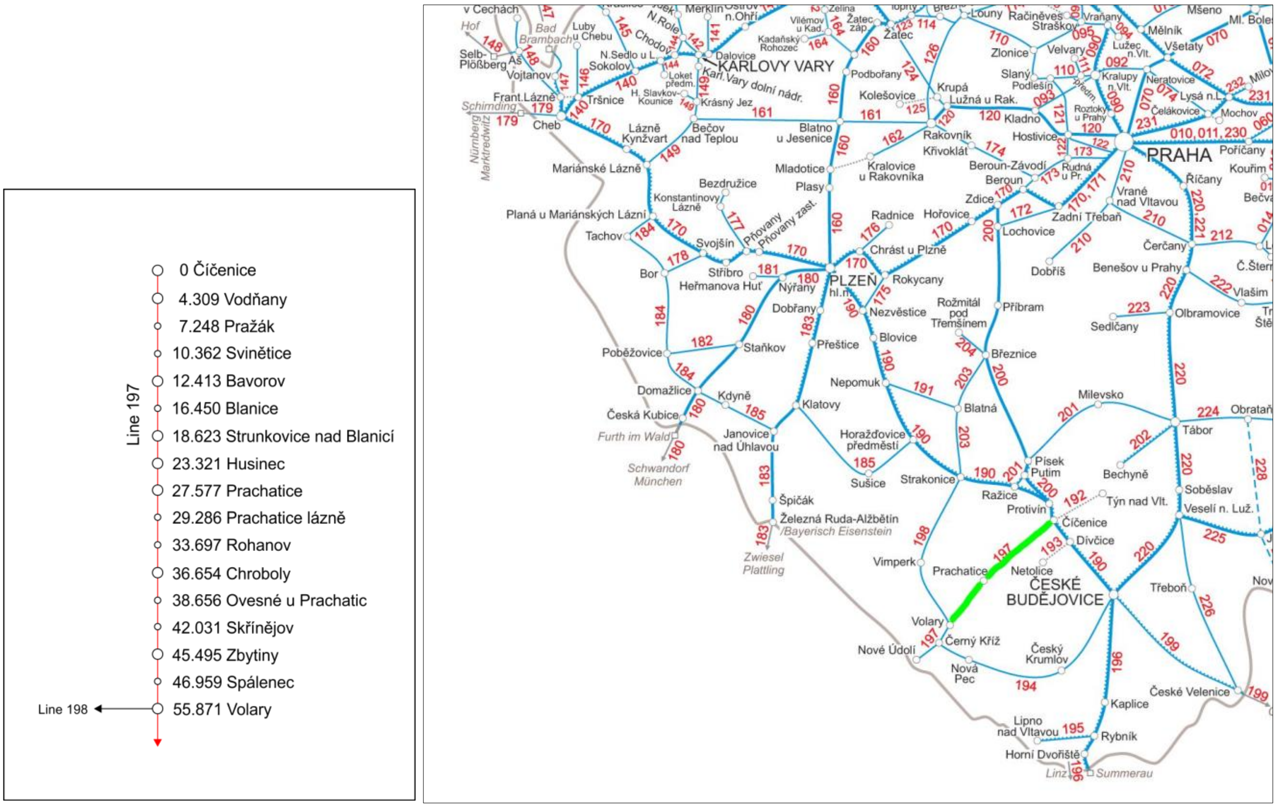

Figure 24: Test track operated by DMU 814-914 Regionova

Category	Description	Rating
Vehicle type	814-914	-
Operator	Czech Railways	-
Address	Nábřeží Ludvíka Svobody 1222, 110 15 Praha	-
Contact Person	ing. J. Konečný phone: +420972233870 e-mail: konecnyj@gr.cd.cz	-
Track type	Commercial train running on regional line with valleys, overpasses, woods	High
Size of used railway net	56 km total distance from Číčenice to Volary	High
Geographic track data	The survey has been performed by a certified company GB Geodézie supported by Research Institute of Geodesy, Topography and Cartography, v.v.i. and AZD Praha.	High
Accuracy of geographic track data	All the objects of the line are provided in WGS-84 coordinates and the entire track from Číčenice to Volary has been surveyed. The GPS data has been collected with laser scanning method supported by RTK/INS by a certified company and a database with all the relevant information in text format is available.	High
Validation of track data	Independently checked by AZD Praha, RTK/EGNOS GPS measurements.	Medium
Reference points	**RFID tags,** Milestones, Level crossing, Speed indicator boards, Switch points	High
Number of reference points	**about 130 RFID tags** (located in each 0.5km + additional for track discrimination in the stations with parallel tracks)	High
Position of reference points	All along the line	High
Track chainage	Available	High
Engine type:	Diesel	-
Max. speed:	80km/h	High
Quality of speed reference	<3%	High
Speed reference	Wheel tachometer will be installed	High
Approval	Installation has to be approved by Rail Authority in Czech Republic	High
Costs	Equip of vehicle, tracks (RFID tags) and maintenance of measurement system: 20K €	High

Category	Description	Rating
Next installation date:	After approval of installation design, within any service inspection in depot	High
How often are test runs scheduled?	Daily operating train	High
Reference time on board available	GPS Time (GPS receiver independent from STARS installation)	High
Installation space	Space between vehicle roof and interior ceiling is available for installation of equipment	High
Data download in depot	Possible, not only in depot but at the end of each train run	High

5 REFERENCES

[1] STARS Grant Agreement, Annex I - "Innovation Action", 25th of November 2015.

[2] STARS Consortium Agreement of 6th November 2015.

[3] STARS WP2 D2.1 Specification of the Measurement Information, 20th of April 2016.

[4] STARS WP2 D2.2 Measurement Procedures Specification, 16th of May 2016.

[5] STARS WP2 Technical Note on Definition of the Criteria for selecting the Railways Lines / Sites for preparation of D2.3 Identification of the Representative Railway Lines / Sites, 23rd of May 2016.