



BSI Standards Publication

Space – Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) – Field tests definition for basic performance

National foreword

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English version

Space - Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) - Field tests definition for basic performance

Espace - Utilisation de la localisation basée sur les
GNSS pour les systèmes de transport routiers
intelligents - Définition des essais terrains pour les
performances générales

Definition von Feldtests für Grundleistungen

This Technical Report was approved by CEN on 23 February 2020. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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European foreword

This document (CEN/TR 17465:2020) has been prepared by Technical Committee CEN/TC 5 “Space”, the secretariat of which is held by DIN.

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1 Scope

This document is the output of WP1.2 “Field test definition for basic performances” of the GP-START project.

The GP-START project aims to prepare the draft standards CEN/CENELEC/TC5 16803-2 and 16803-3 for the *Use of GNSS-based positioning for road Intelligent Transport Systems (ITS). Part 2: Assessment of basic performances of GNSS-based positioning terminals* is the specific target of this document.

This document constitutes the part of the Technical Report on *Metrics and Performance levels detailed definition and field test definition for basic performances* regarding the field tests definition.

The purpose of WP1.2 is to define the field tests to be performed in order to evaluate the performances of road applications’ GNSS-based positioning terminal (GBPT). To fully define the tests, this task addresses the test strategy, the facilities to be used, the test scenarios (e.g. environments and characteristics, which should allow the comparison of different tests), and the test procedures. The defined tests and process will be validated by performing various in-field tests. The defined tests focus essentially on accuracy, integrity and availability as required in the statement of work included in the invitation to tender.

This document will serve to:

- the consolidation of EN 16803-1: *Definitions and system engineering procedures for the establishment and assessment of performances*;
- the elaboration of EN 16803-2: *Assessment of basic performances of GNSS-based positioning terminals*;
- the elaboration of EN 16803-3: *Assessment of security performances of GNSS-based positioning terminals*.

The document is structured as follows:

- Clause 1 is the present Scope;
- Clause 5 defines and justifies the global strategy for testing;
- Clause 6 defines and justifies the retained operational scenario;
- Clause 7 defines the metrics and related tools;
- Clause 8 defines the required tests facilities;
- Clause 9 defines the tests procedures;
- Clause 10 defines the validation procedures;
- Clause 11 defines how to report the tests results.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16803-1:2016, *Space — Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) — Part 1: Definitions and system engineering procedures for the establishment and assessment of performances*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

4 List of acronyms

- | | |
|----------|---|
| ▪ GNSS | Global navigation satellite system |
| ▪ GPS | Global positioning system |
| ▪ SBAS | Satellite based augmentation system |
| ▪ COTS | Commercial on the shelves |
| ▪ GBPT | GNSS based positioning terminal |
| ▪ OTS | On the shelves |
| ▪ ITS | Intelligent transport systems |
| ▪ ETSI | European telecommunications standards institute |
| ▪ A-GNSS | Assisted GNSS |
| ▪ FAR | False alarm rate |
| ▪ PFA | Probability of false alarm |
| ▪ PMD | Probability of miss detection |
| ▪ PPK | Post processing kinematic |
| ▪ AIA | Accuracy, integrity, availability |
| ▪ SW | Software |
| ▪ LoS | Line of Sight |

5 Definition of the general strategy: what kind of tests?

5.1 General

The technical solutions for ITS (road environment), focused in the targeted standard, are more and more complex.

One consequence is that their performances and behaviours will no more only depend on their design but also, and strongly, depend on a lot of external situations and parameters, uncontrolled by the stakeholders. Among those parameters, we can quote the dependencies on the status of international worldwide space systems (GNSS), on physical atmospheric conditions, and other environmental conditions in the proximity of the vehicle (traffic, tree foliage, buildings in vicinity etc.).

As an example, this situation implies that any realization of one field test procedure of a given product at a given date and hour, will give a different result than the same test procedure of the same product in the same location at a different date and hour (neither ergodic nor stationary stochastic process).

The obvious consequence is that, if a pure field test strategy is targeted as a preferred solution for the performance assessment aiming homologation of devices, the analysis of the tests results would require specialists, and may frequently result in intangible and unreliable interpretations, the opposite of metrology.

A solution to avoid this issue is to have a total trust in simulations where all the tests conditions are controlled and which could be perfectly repeatable. ETSI addressed a similar issue during its standardization process targeting the GNSS based Location Based Services (See ETSI TS 103 246-1, -2, -3, -4, -5). As a conclusion of its work, ETSI, selected a solution exclusively based on simulations (see Annex A).

Considering that the real-life environment remains complex to be simulated, the pure simulation technique will lead to scenarios with a very great number of parameters to be set-up, inducing risk of human manipulation errors, and anyway a remaining lack of representation of the reality.

New paradigms have to be seriously considered, and this Clause 5 aims to open solutions by analysing the best way to select and phase the tests to be performed in a standardized performance assessment.

5.2 GBPT characterization

5.2.1 An hybrid and heterogenic system

According to Figure 3 of (see EN 16803-1), Positioning-based road ITS system is the integration of the GBPT into the road ITS application. Moreover, GBPT is presented also as a complex assembly of sensors, with multiple interfaces with external systems.

The positioning level, focused in this part of document for the definition of tests, is still an assembly of more or less complex components where at least one (1) component is a GNSS sensor.

The generic architecture of a Road ITS system ((EN 16803-1), Figure 4) shows directly that the evaluation of the metrics related to the positioning (accuracy, integrity, availability) will be complex, since it:

- covers intermediate outputs (position, speed) of a global integrated system, likely not easy to capture in some future finally packaged and installed products: *specific prescriptions and communication protocols should be standardized*;
- *depends on worldwide and independently evolving infrastructures*, namely GNSS infrastructure and telecommunication networks, interacting each other's (Assisted, Differential GNSS) and with the system itself, and in particular influencing strongly its performances;

- covers *sensing of the external environment*¹ and consequently *depends on a huge number of external environmental conditions* (radio propagation for GNSS and telecommunications, light, fog and dust for cam and LIDAR, etc.);
- covers in the same time *sensing of the motion of the vehicle*² through odometers and inertial sensors and consequently depends on the vehicle and its driving as well as additional external environmental conditions (ex: meteorological, or road-holding for odometer).

In EN 16803-1:2016, Clause 8 presents a long (even if not exhaustive) list³ of parameters which should impact the definition of the tests.

Synthesizing together, namely in an integrated lab test facility, the effects of worldwide radio infrastructures (as existing currently or evolving in the future), their local radio propagation in road environment, the motion sensing by inertial sensors, and others phenomena like climatic for odometer or imaging for computer vision is today unfeasible.

Today, the lab facilities for making tests in the environmental conditions interesting each sensor exist separately but are never integrated.

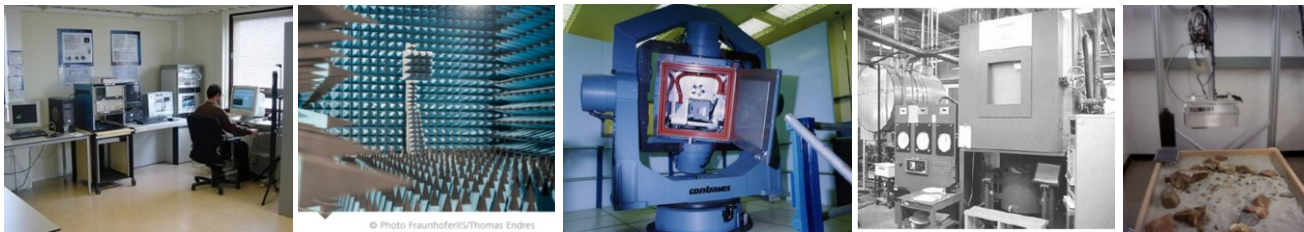


Figure 1 — Typical test bench in laboratories facilities

Left to right: GNSS signal generation (ESA radio navigation lab), radio oriented for radio navigation or telecommunications, motion oriented and climatic oriented for inertial sensors (AIAA 092407), computed vision oriented (JPL robotics facilities)

However, techniques like fusion of sensors and data (e.g. maps) appear more and more mandatory to leverage the potential of automotive applications and businesses, considering the weakness of the GNSS signals propagation environments.

5.2.2 Test combinatory explosion: an issue

It is the purpose of sensor fusion to make each sensor impacting (improving is expected) the performances of the hybridized solution. However, each sensor has two (2) types of errors:

- principles: imperfections of the used physic law modelling the real world (ex: the GNSS propagation is line of sight, except when refraction like in ionosphere or reflection like multipath are encountered, accelerometer measuring only the sum of motion acceleration and gravity, etc.);
- measures: imperfections in the design and manufacturing (ex: bias and scale factors in inertial sensors, thermal noise in electronic, etc.).

¹ Also called 'exteroceptive' sensors: GNSS sensors, cam, LIDAR measure physical phenomenon of their extern environment to deduce location data, to be compared to eyes, nose, (...) on the animals.

² Also called 'proprioceptive' sensors: inertial units, odometer measure physical parameter changes due to motion in order to deduce location data, to be compared to sensors belonging to muscles on the animals.

³ In particular when the performances of other sensors than GNSS are considered – required for hybridized systems.

By capturing information from a lot of parameters of the external environment or from the motion, and because many physical principle errors of the measurements exist in the reality, the sensor fusion multiplies also the risks of performance degradations. A strict performance assessment should consequently measure the performances in any combination of favourable/unfavourable conditions for good measurements, sensor by sensor. For GBPT, these combinations are still to be combined to the multiplicity of the road usages, road environment varieties, and finally combined with the multiplicity of installation and set-up in the vehicles. There are then a so vast set of possible combinations that it becomes incredible to build reliably and exhaustively the list of the necessary test scenarios covering correctly the computation of performance metrics.

This combinatory explosion affects as much the lab tests in terms of facilities and scenario diversity, as the field tests or the simulation techniques, where, in addition, some of the physical effects are very complex to model representatively.

This implies that experimenting field tests (where the sensors capture during each test one true representation of the real life, namely one instance at a given instant and in a given location of all of the parameters which control the GBPT performances) provide a unique and not reproducible representation. This representation is thus unable to provide, on one test, whatever its length, a total characterization of the statistical properties (like expected in the metric definition).

In this sense, GMV experiment on Madrid (TR WP1/D1) illustrated that very well: 12 samples of a similar procedure (same location) have been run giving 12 separate cumulated distributive functions of the accuracy metric:

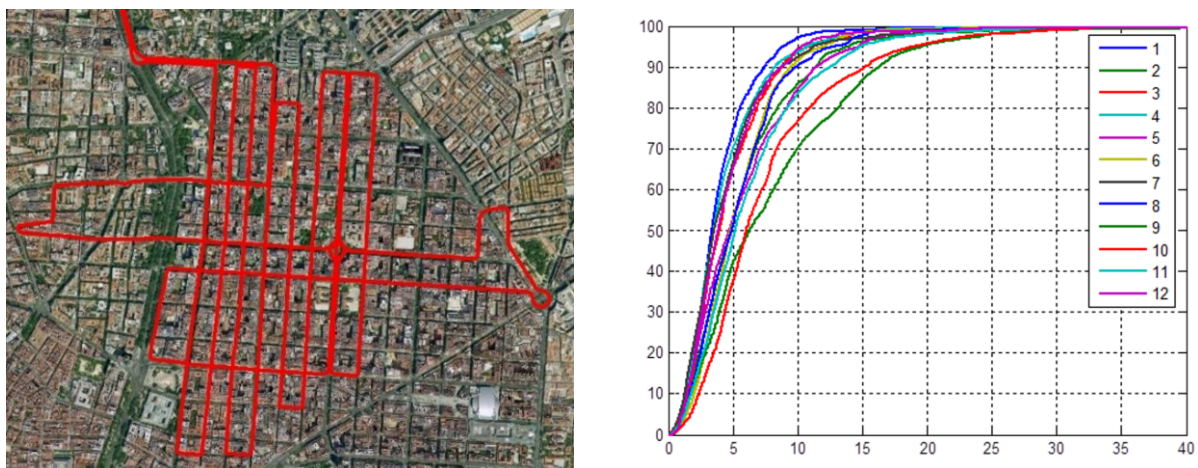


Figure 2 — Diversity of field tests results [TR WP1/D1]

This experiment shows that the metric itself, as assessed by field tests, becomes a random function, with a significant dispersion and that the field test proposition gives a non-ergodic random process, preventing to become the best solution for the selected metric assessment.

A more practical approach should then be agreed in the standard, preventing useless, unreasonable testing effort and costs.

The combinatory explosion finally prevents an exhaustive coverage by the metrics of all environmental situations impacting the performances.

5.2.3 Proposed approach

In EN 16803-1, the standardization working group has already and clearly separated the performance of the application in two (2) layers:

- the positioning level with the GBPT;

- the ITS application level.

The described previously problematic necessities to propose an additional breakdown in several sub-problematics.

The proposed approach to deal with the GBPT (hybridized systems) performance assessment through testing is to impose a dichotomy between additive sensors (supplemental with respect to geolocation) and primary sensor (GNSS) and positioning solution, as identified on the Figure 3.

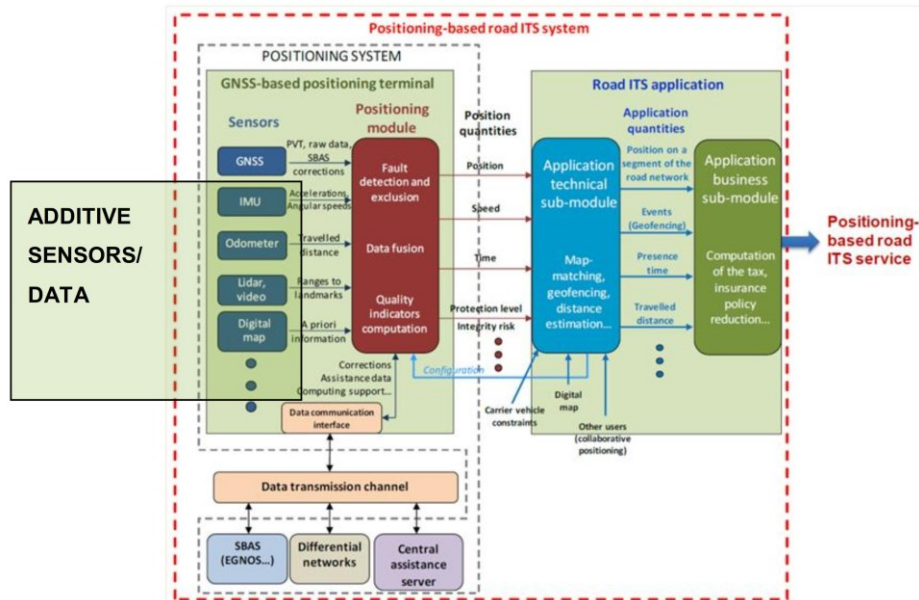


Figure 3 — Proposed approach for the testing requirements

It should thus be retained for the future ITS applications a gradual verification and homologation process.

This process could support three assessment levels:

- additive sensor level:
 - separately, inertial sensors, odometer, vision sensors should be evaluated in terms of performance, with their own metrics (e.g. measurement errors on ranges to the landmarks for LIDAR, video, opening range[...], accelerometers biases, gyro drift, etc.);
 - at their manufacturing level;
 - covering, for example with lab tests, quasi exhaustively the specific environmental conditions, up to limits of functioning, which affects their performances (weather, road grip, vibrations in addition to motion, dust, etc.);
 - leading to characterize separately the sensors with labels and classifications;
 - leading to propose, for each sensor device an 'equivalent reference additive sensor' and/or a 'additive sensor model'.
- GNSS based positioning level (optionally including fusion of sensors and data):

- o for the test purpose, the *GBPT device under test shall be able to receive GNSS signals* (radiated or conducted according to the antenna integration level);
 - o for the test purpose, the GBPT device under test shall be able to receive ‘reconstructed test stimuli’ in place of each integrated additive sensors (necessitates standardized input/outputs protocols);
 - o the scenario list shall represent a selected set (not exhaustive) agreed typical but realistic combinations of operational situations as input/outputs of any sensors (including GNSS) so that the fusion of sensors could be tested in, without trying to reach an exhaustive set of situations.
- *application level*: PVT error models and sensitivity analysis as proposed in EN 16803-1.

In the above proposal, one should understand that:

- ‘equivalent reference additive sensor’ means a COTS sensor (among a list of homologated devices) of same nature (inertial, odometer, visual) and same class of performances giving similar availability behaviour and performances statistic behaviours, possibly used in GBPT field test for capturing data;
- ‘sensor error model’ means an open SW model dedicated to one sensor kind (inertial, odometer, etc.), whose inputs are physical parameters of the environment, like temperature, pressure, humidity [...] which may be easily measured during a data collection (possibly acquired during the GBPT field tests) and sufficient to describe the performance behaviour and availability of the sensor;
- ‘reconstructed test stimuli’ are data resued either from the ‘equivalent reference additive sensor’ capturing directly the environment during field tests, or from the ‘additive sensor model’ using inputs issued data acquired during field tests (temperature, pressure, humidity, etc.).

At positioning level, only an agreed selection of typical operative situations would have been performed in field tests (or recorded for ‘Record and Replay’ solutions), avoiding the combinatory explosion. That necessarily assumes that at lower level of manufacturing, sensors have typically be submitted to a quite exhaustive coverage of any environmental conditions, comprising the limits of the operating domain in order to get enough trust in a sensor model or in a reference sensor.

It is not in the scope of this document to go further in the definition of the process dedicated to the characterization of additive sensor level, for which the involvement of the own industry (inertial units, vision, wheel coding) is mandatory. *We only recommend opening a complementary process to standardize those issues, which are of utmost importance to address hybridized systems.*

We now assume in this document that the proposed approach might be retained, that ‘equivalent reference additive sensors’ are existing and known as well as ‘additive sensor error models’, and that the standardized interfaces with additive sensors for test purposes are also known.

5.3 Stakeholders and responsibilities

5.3.1 Industry value chain

The life cycles of the development, production, integration of the electronic devices are industrials features depending on the business models usually applied in the corresponding market.

To illustrate the GBPT for road ITS application, it is interesting to refer to the value chain elaborated by the GSA (GNSS market report for road applications). This value chain allows to identify the

industrial actors and how they play a role and have responsibilities in the final positioning performances and testing:

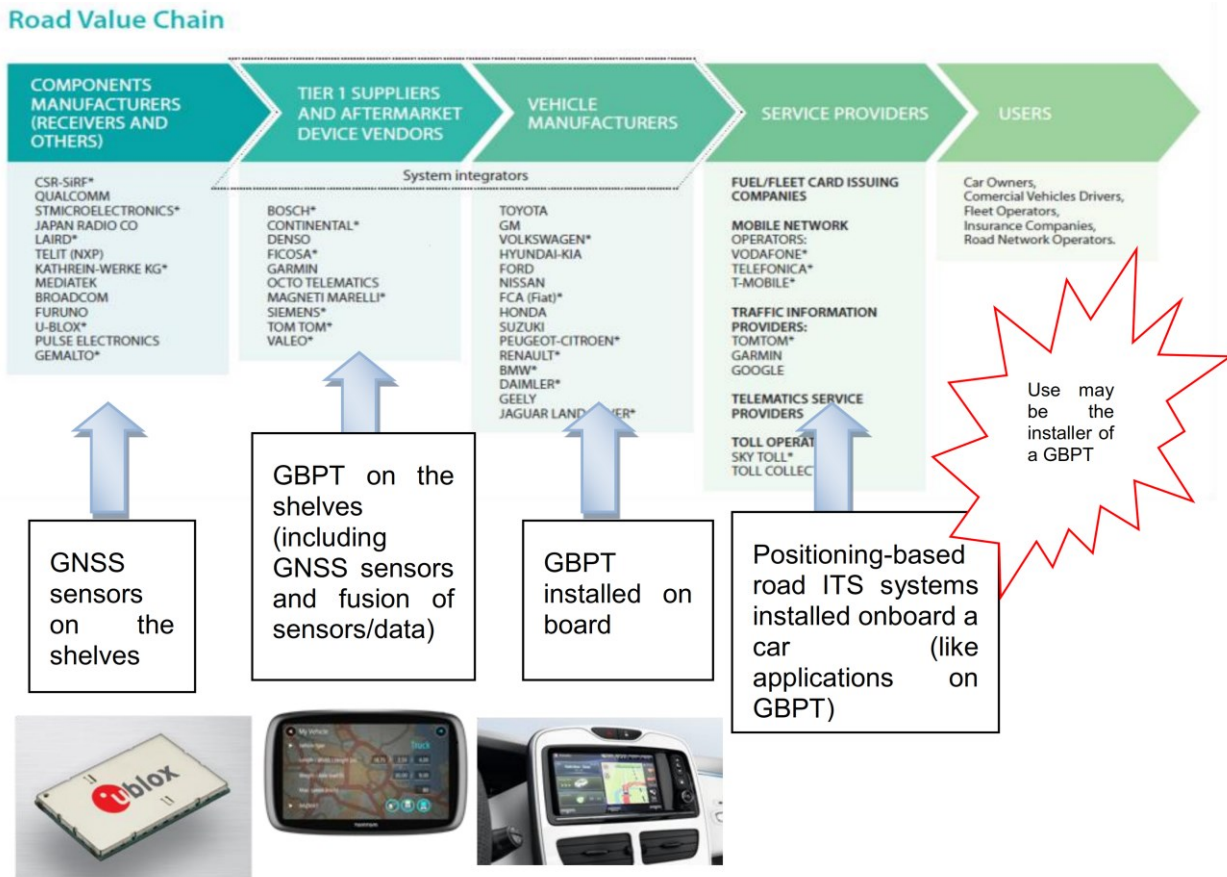


Figure 4 — Road value chain (according GSA market report)

5.3.2 Roles and responsibilities

The various cycles of products industrialization are to be considered in order to define a cost-effective test strategy and phasing, up to an optional homologation or certification process for ITS operations by adequate authorities and government bodies.

This way:

- The *GNSS sensor (electronic radio chip) manufacturer* has a first major responsibility in the final GNSS positioning performance once embedded in the car, but can only test its production out of this context; It will never take the complete liability regarding neither the ITS application nor the road application. Having created a general-purpose device, it has no interest to particularly invest for testing the road ITS applications, even if it cannot ignore this mass market. In the opposite, it has the maximum skills to know how the final GNSS performances can depend on its product for one part, and its integration in the second part. Finally, it is not necessarily an antenna manufacturer even if it defines recommendations for these appendices.

- As well, the *additive sensors manufacturers* (inertial units, cameras or LIDAR, etc.) or data providers, which are not specifically mentioned in Figure 4 because out of scope of the pure GNSS value chain have also a clear responsibility in the final GBPT positioning performance when hybridization or fusion of sensors are used. They too may have created a general-purpose device and not a road specific one, have the maximum skills to know how the performances of their sensors can depend on their products themselves, of the operational conditions where they work (for example face sunlight, fog and humidity for the cameras, etc.) and finally, of their integration in the vehicle. The sensor manufacturers shall provide a clear statement about these performances and limits of operation and should provide clear recommendations for the integration and installation.
- The *GBPT manufacturer integrates the GNSS sensors* with other sensors, data and has a major responsibility in the final positioning performance on board the vehicle. It is more specialized on road applications than the sensor manufacturer, and will invest in specific means and models for stimulating the internal sensors and for testing the integration on car, maybe recommending the best integration and installation. While keeping a distance with the final ITS application for avoiding a too customized product, it will still remain independent from the car manufacturer in order to keep the potential of its market, but will certainly build strong partnership with some of them. It can, but not necessarily, integrates the antenna, and also depends, for the final performances, on some final installation concepts. *Therefore, it should occupy the best stage for endorse a black labialization⁴ of its product on the shelves, with respect to the GBPT positioning performances* and participate to the elaboration of a technical agreement for integration and installation of the dedicated electronic devices allowing to finalize the certification of a particular ITS application. The main test effort with respect to the standardized accuracy, integrity, availability performance assessment should take place with these manufacturers, considering a variety of situations in terms of propagation environment even if it should well be noticed that it is only a “on the shelves” evaluation, therefore rather a “lab” evaluation. At this stage, conducted tests are preferable, using either simulations or replays.
- The important step to be held by the *vehicle manufacturers* (and system integrators for the second market if any) should be the setup of the facilities components of the final integration of the GBPT like power supply, communication buses connections, computing resources, antenna location and fixation, mechanical interactions between GBPT and vehicle, location of the system (antenna, inertial unit, etc.) with respect to the dynamic figures of the vehicle motion (centre of gravity, centre of rotation, etc.). None of these facilities is the core of the positioning functions but almost all have an impact on the final positioning performances assessment (power micro-cut duration as an example, or vibrations). The process will depend on each vehicle's model (each first or modified installation) and therefore, even if a same GBPT on the shelf is retained in this process for several models, a particular field test campaign of the final installation should be led for verifying the overall positioning performance in a good functioning verification. At this level, the goal should not be to cover any propagation situation with respect to environment (atmospheric, rural/ cities, etc.) but to cover real situations of radiated signals, electromagnetic compatibilities between each connected component [...]. (as an example GNSS and A-GNSS with entertainment applications, etc.) and finally dynamics coverage for the inertial and other proprioceptive sensors. Thus, we address here *field tests of the same nature than currently performed by this industry*.

⁴ Under ‘black labialization’ we mean that an homologation process is done here, on the black box product, before it can be put on the shelves for commercialization towards further automotive integrators. This homologation process can be performed against one or several authorized ITS application groups or use cases (for example road tolling could be one of them aiming a set of metric classes, autonomous navigation could be another corresponding to other set of metric classes, etc.). The homologation process concludes to grant a ‘black label’ to the black box, like an official CE label (CE). This label should give its customer an insurance that it can make a safe use of the black box, as far as it does not open the box, as far as it conforms with the recommended installation and make a use in conformance with the authorized ITS applications groups and use case for which the black label was granted.

- The service providers are typically involved in the *ITS applications* and shall be responsible for the setup of the ITS application End to End performance assessment, but as well specified in the EN 16803-1 standard, they should essentially operate *sensitivity analysis*. It could be essential, however, that they would perform a new final field test covering a sample of the PVT error model, each time that a new GBPT is used in the ITS application so that verifying that the new product plays effectively the PVT error model used in the sensitivity analysis process.

5.4 Main criteria for testing strategy

The main criteria driving the definition of standardization/certification tests can be sorted by their type of effects and their impacts:

- *trustable metrology*: The definition of the tests, from the detailed definition of the metric to be evaluated up to its final assessment shall follow the great principles of the metrology:
 - o reproducible (with similar results) from one test to another, from one lab in responsibility to another, from one location to another;
 - o representative and meaningful with respect to its objective, here road ITS applications;
 - o reliable: the whole procedure of the metric assessment shall provide indisputable results, involving the required instrumentation quality, the required skills for personal, the required integrity in results interpretation.
- *cost efficiency*: The definition of the tests shall keep a reasonable cost for any potential manufacturer, cost being induced by:
 - o cost of the test benches: instrument, infrastructure, vehicles, etc.;
 - o cost of the test operations from preparation up to the reporting of the tests results, in particular due to their duration and consequent manpower costs;
 - o cost linked to the remoteness between tests laboratories and industrials, in terms of location, or in terms of practices in the value chain;
 - o cost linked to the interoperability of the test bench with respect to various technical solutions under tests.
- *authorities and responsibilities*: in the definition of the tests, the organizational part and the sharing of the responsibilities between all the involved actors shall be very clear and be operative with respect to the various industrial life cycles in the value chain in one hand, with respect to the capability to grant certificates for operations or unified labels to the marketable products:
 - o sharing the tests responsibilities with the industrial communities: as an example, to illustrate, when test results depend on antenna setup, it is preferable to perform the test with the car manufacturing level than with the ITS GNSS receiver manufacturing level;
 - o sharing the responsibilities between European laboratories: the European standard shall enable the performance of tests in any European nations without imposing a unique lab offering a interoperable enough standard in a worldwide competition: if the definition of tests required a field test absolutely performed in Toulouse, Madrid or London city, etc., an unfair competition could be not sustainable for devices international exchanges (import and export), and finally deserve European automotive industry.

Some detailed discussions about the criteria are provided in Annex B.

5.5 Potential test methods

5.5.1 General

Historically, only two (2) types of tests were carried out in the domain of GNSS-based positioning:

- simulations in lab tests with a GNSS signal generator;
- field tests.

Since for few years, a third technique has emerged, the so-called 'Record and Replay' technique, also called 'Log and Replay' technique, or 'Record and Playback' technique, all these names recovering the same process.

5.5.2 Simulations

The simulation in lab test assumes the use of *GNSS signal generators* (hardware and software generating RF signals), optionally completed by virtual reality for the *simulation of the radio propagation*. The scenarios are described in *simulation scripts*. The more the scenario refines the reality of true operations, the trickier is the simulation script.

The GNSS signal generator can be used in two (2) kinds of test bench:

- *conducted* tests where the signal input is at RF cable level, offering a partial view of the final operation where the antenna setup is of the utmost importance;
- *radiated* tests where the signal input is at antenna level, offering a better view of the final operation but at the cost of a controlled radiation environment demanding additional installations like anechoic chambers (car size for road applications), and instrumentation to control the noise figures.

Both GNSS signal generators and additional facilities have limited features in terms of representation of the global environmental conditions. But they cannot be ignored for specific cases, since all parameters are controlled and that some rare events, like satellite payload failures, can be also inserted in the tests scenarios. For dynamic tests, the trajectory of the vehicle is simulated and therefore the parameters of the reference trajectory are perfectly known.

The GNSS Signal generators may now be *enriched by 3D model* for finer representing the environment and its induced propagation features (signal occultation by buildings, attenuation, geometric and electromagnetic multipath representation more realistic than initial).

Some of GNSS Signal generators are able to create stimuli for hybridized systems, by simulating additional sensors, among them inertial or odometers based on the vehicle motion simulation. In this case, the sensor model is integrated by the GNSS Signal generators manufacturer, and can be parameterized in the scenario script.

In the case where the GNSS Signal generator manufacturer would not have integrated a correct sensor model, the standard should impose for the GNSS Signal generator to be open for integrating new sensors models, similar to 'sensor error model' as output from the sensor level characterization and homologation phases (as described in subclause 5.2.3).

5.5.3 Field test

Usual definition of '*field tests*' is: using a *road trip* (optionally a specific circuit), a *representative vehicle*, the device under test installed in the vehicle in a representative manner, in particular *receiving the signal broadcast by the GNSS constellations, in the real propagation channel*.

The *static field test* is the trivial case of field test where the vehicle is not mandatory, the road trip is replaced by a single point (whose geographic coordinates should be well known).

The *dynamic field tests* require a complementary instrumentation in order to have an accurate access to the *reference trajectory*. Since no other trajectography means exist in land applications than GNSS' ones for a positioning in geographic frames, the trajectography means uses an enhanced GNSS receiver using post processed corrections provided by RTK networks for a sub inch level of accuracy, as well as a high end inertial system to reduce the unavailability or unreliability of GNSS positioning in stringent propagation environment.

However, in field tests, the device under test is stimulated with *uncontrolled environmental features*, that remain unknown and uncontrolled, rarely reproducible from one run to another. This situation brings with it large difficulties to interpret the results, and difficulties to get undisputable results, undisputable statistics of results, as shown by experience (see Annex B.1.1).

5.5.4 Record and Replay

The 'Record and Replay' technique *starts on the field, by recording* of the test data collection according to an agreed scenario. This step should guarantee a *high fidelity digitalization of numerous parameters, in particular the capture of radio signals* issued from the worldwide infrastructure (GNSS and telecom) in a realistic local environment of propagation. It *ends in the lab to replay infinitely the same scenario*, using exactly the same radio signal inputs and the same environmental conditions of reception.

With respect to simulation, the 'Log and Replay technique' offers a better representation of reality since it comes from real situations, but less flexibility of tested situations (rare events are unlikely). The chance to integrate a satellite failure in one recorded test scenario is near to zero. However, as with simulations, a lot of devices can be tested in exactly the same conditions.

With respect to field tests, the 'Log and Replay technique' offers better metrological features since the repeatability can be reached.

It also saves money, since the setup of the test bench for recording is similar to one field test, but after that the setup of the test bench for replaying is largely less expensive, and enable to test a multitude of receivers with less additional cost.

Finally, a very interesting feature of the 'Record and Replay' solution, is that *the interface between the record phase and the replay phase is a repository of files*, offering capabilities like copies and licensing, cut and paste (in smaller files if a customization by application would become necessary as an example, etc.), browse, etc. Today, the amount of data are quite huge for storage techniques (2 TB/min of recording), but feasible for hours, and it is expected that in few years, improved solution could be available (currently no data compression is used).

Data set repositories, issued from the works performed by few GNSS-specialized and homologated (ISO/IEC 17025) laboratories for recording data, according agreed procedures by this standard, could become themselves standardized scenario definitions, enabling homologated test cases to be replayed by a larger panel of homologated, not GNSS-specialized laboratories.

This feature has a true interest in the worldwide economy. First it enables to make in Tokyo a field test recorded in Paris, or inversely to replay anywhere in Europe and with few expenses a record performed in Shanghai. Moreover, it is interesting, as an additive business model for GNSS, offering a European capability to export standardized data sets towards other regional economies, enabling worldwide competitors to accept and apply the European standards, and even promoting the European methodologies to be extended to world.

Concerning additional sensors for hybridized systems, once the 'equivalent reference additive sensors' would have been selected by the sensors manufacturers, they could be added in the test facilities and procedures for the recording part of the scenario. The corresponding recorded data files could be further translated in order to create the 'reconstructed test stimuli', enabling sensors stimulation for the hybridized systems during the replay. The reconstructed test stimuli would be then:

- be consistent and synchronous to the GNSS signal scenario;
- have a true representation of the test (vehicle motion for example) and true real life in terms of measurements errors due to the environment;
- easy to use for the replay.

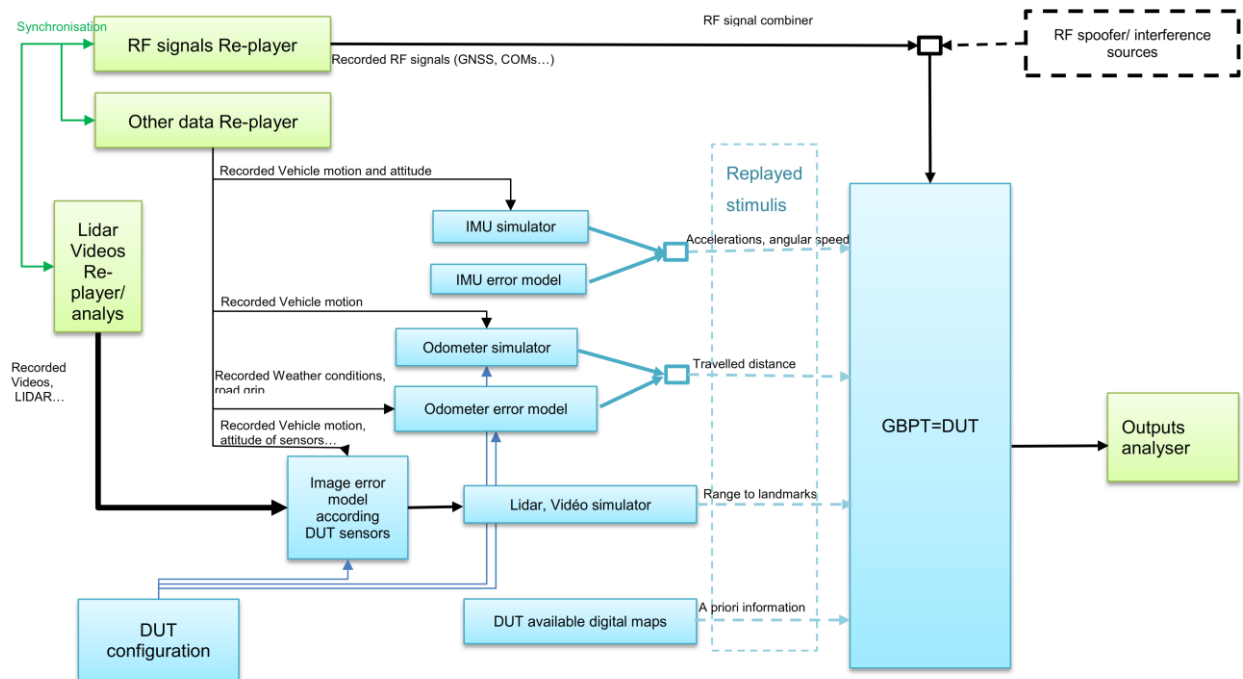


Figure 5 — Replay test principles proposed for Hybridized DUT

In the Figure 5, the green boxes are representing the tests facilities brought by the lab, and the blue boxes are elements representing the tools, data and devices brought by the GBPT manufacturer for the aim to test and homologate its hybridized device.

It is required that the corresponding interfaces between test facilities and DUT tools and devices are all standardized, or if not, the GBPT manufacturer should give all information and tools for the aim of the test bench final definition and integration, up to the output analyser.

5.5.5 Verification methods face-off table with regard to main criteria for testing strategy

Each of the described test kinds has advantages and drawbacks:

Table 1 — Verification methods face-off table with regard to main criteria for testing strategy

	Method\ attribute	Field test	GNSS Signal simulator	GNSS Signal simulator + 3D model	'Record and Replay'
Trustable metrology	Reproducible (No = X, Yes = ✓)	X	✓	✓	✓
	realistic for road (No = X, Yes = ✓)	✓	X	Partially representative	✓
	reliable procedure: Controllable (No = X, Yes = ✓)	X	✓	✓	partial
	reliable procedure: Reference truth (No = X, Yes = ✓)	X ^a	✓	✓	b
Cost efficiency	Test bench cost (high = X, low = ✓)	✓ Static	±	±	✓(N replays)/ ± (one (1) record) ^c
		X Dynamic			
	Test operation cost (high = X, low = ✓)	✓ Static	✓	✓	✓(N replays)
		X Dynamic			
	Cost for reference truth (accuracy and integrity tests) (high = X, low = ✓)	X	✓	✓	X (only one (1) record)
	Remoteness/customers/value chain practices (Yes = X, No = ✓)	✓	X ^d	X ^d	✓(N replays)
Responsibilities	Sharing the test responsibilities (lab /industry) (No = X, Yes = ✓)	±	✓	✓	✓
	Sharing the test responsibilities/European nations (No = X, Yes = ✓)	±	✓	✓	✓
	Worldwide sharing (No = X, Yes = ✓)	X ^g	✓	✓	✓

NOTE From this Table, it is clear that the 'Record and Replay' kind of test offers the best compromise on the totality of the criteria.

^a Except if a specific mean and procedure is used for measuring and computing the reference trajectory, there is no accurate knowledge of the truth (in particular in dynamic tests). See line 'cost for reference truth' which is required to establish accuracy and integrity metrics. An issue of unreliability of the field test is caused by the establishment of the truth reference. Different quality between reference truth means bring different results of tests (metrics).

^b The reference truth is the same between record and replay, If it has been established during record, it is reusable for replay, and repeatable for any replays, making the metric evaluation at a same level of reliability. There is really a difference between field tests reliability and R&R reliability: in R&R the truth reference is not

	Method\ attribute	Field test	GNSS Signal simulator	GNSS Signal simulator + 3D model	'Record and Replay'
	known during record, like in field tests. But the tests and qualification of the GBPT are done only on replay, with a common basis of reference truth for all GBPT, which is not the case for field tests. Consequently, even if the quality of the reference truth is not the highest, it is the same for any GBPT. ^c The cost of the record test bench is higher than the replay test bench because of the required vehicle installation. ^d Requires specific skills in GNSS except if the simulation scripts would be open and standardized. ^e Requires specific models for sensor fusions. ^f Might be facilitated by the acquisition of data from additive sensors data during the record by using the 'equivalent additive reference sensor', replayed as well as the digitalized GNSS signals or the usage of 'additive sensors model' as defined previously and using compatible acquired data from external environment. ^g The GNSS DOP conditions are depending essentially on latitude conditions. Field tests uses real DOP conditions (not externally controlled), therefore field tests are not equivalent worldwide, while DOP conditions are not the result of the GBPT, but the result of the GNSS infrastructure availability (notion of Signal In Space (SIS)) and shall not be allocated to GBPT metrics. In simulation, you can impose European DOP, in 'Record and Replay' you can impose European record, then worldwide replays!				

5.6 Metrics coverage

5.6.1 Need of refinement of the metrics data sets

Three main metrics are defined in EN 16803-1⁵ accuracy, integrity, availability. They are all to be issued from the values and figures of merit of the position and velocity outputs (considered figures of merit: validity and protection level).

Accuracy and integrity metrics are recognized as non-Gaussian random variables, from which several percentiles of the CDF (50th, 75th, 95th) are to be evaluated.

Availability is represented by a time percentage.

At the moment of redaction of this document, no definition of the basis of computation of the CDF (data set) is defined in the EN 16803-1, neither its size, nor the conditions of the collection of data or the method to extract the data set from a data collection, taking into accounts the correlation time constants or other similar important aspects for the statistical behaviours.

Therefore, it would be one of the main objectives of this document to give a more detailed definition of the data sets above which the evaluation of the metrics will rely, through the test scenario definitions (Clause 5 and Clause 6), the methods and tools for the computations (Clause 7 and Clause 8) and the procedure descriptions (Clause 9 and Clause 10).

Unless this definition, the metrics keep a too large spectrum of possible interpretations.

5.6.2 Unique data collection for the accuracy, availability, integrity metrics

Accuracy, integrity, and availability (AIA) should be evaluated from a unique collected data set.

There should not be one data set collected for accuracy, another data set for integrity and a third for availability.

⁵ In conformity with the statement of work of the project, the timing metrics are not in the scope of this document. We make an exception with TTFF which is an important operational figure.

Indeed, these performances are totally linked in the applicative needs, since a position or velocity output can make sense for any application only if it is simultaneously available (declared as valid), accurate (at a certain level), and that we can have trust on it (at a certain level of risk).

We recommend that the three (3) metrics would be established on the same data collection campaign since they are actually coupled in the applicative needs. If a position or velocity output is declared available but not monitored or inaccurate (noisy or biased), the application risks to show an uncertain and unexpected behaviour, and consequently lead to not liable or unsafe situations.

In an application, an available position which does not have an accuracy better than the required accuracy for the operation should be discarded at the input of the application, and therefore having the same final impact than an unavailable position.

As well, when liability or safety are playing a role in an application, one declared available position whose protection level is higher than the acceptable position error for the operation should also be discarded at the input of the application, and therefore having the same final impact than an unavailable position.

Indeed, such a situation shows an insufficient monitoring of the displayed or output value of position, these last values could make in consequence uncertain behaviour of the application, leading to a not liable or unsafe situation.

Finally, an accurate and/or well monitored output declared unavailable or invalid make no sense.

5.6.3 Same data collection for a flexible list of road applications

The standard has been setup to deal with a list of ITS applications without distinctions. However, the applications can cover local/global areas, slow/high speeds, etc.

While the global set of ITS applications may cover any type of road trips into any type of environment (and even parking), one selected application could require only low speed near parking locations, or typical places of virtual gantry, etc.

To cover representatively any road applications, the data set collection should cover any type of road trips, with their typical road environment and motion dynamics:

- long range road transport (transnational deliveries, individual/collective European tourism, etc.);
- very short range deliveries (frequent stops);
- quotidian worker journey with typical traffic jam (urban, rural, etc.);
- etc.

More refined descriptions are given in Clause 6.

5.6.4 Particular case of the integrity risk

Concerning the integrity risk, the problematic is quite different since it is important to evaluate the behaviour of the GBPT in specific risky operations.

The integrity functionality is particularly worthy in safety critical or liability critical operations. Its main interest relies on the ability of detection and of exclusion of positioning process faulty behaviours, caused by unexpected situations (feared events) susceptible to lead with the highest probability (with regard to normal operations) towards an accident (safety) or disputable operations like undue payment (liability).

The purpose is to avoid the propagation in the positioning errors of potential rare events (from sensors, from GNSS particular inputs). The proper behaviour for an integer GBPT is to avoid outputting a declared available position while a positioning error greater than the protection level

could be detected, and especially greater than the acceptable alarm limit for the critical operation. This proper behaviour, preventing from Hazardous Misleading Information, while unexpected situations are present upstream the process, avoids the propagation of the effects of rare feared events related to the positioning level in further computations.

Most of the time, failure detection techniques consist in a hypothesis test⁶ Hypothesis test considers a testing function which has an a priori known probability density function (centred χ^2 as an example) when the Hypothesis H_0 – without feared event is true, and another a priori known probability density function, shifted on higher values of the testing function (non-centred χ^2 as an example) when the Hypothesis H_1 – with feared event is true (as shown in Figure 6).

By testing the integrity uniquely in nominal conditions (H_0), the unique feared event which is considered is the exceptional noise sample encountered in the measurement noises, while no feared event is present. This case is represented by the false alarm rate (green hachured area on the Figure 6).

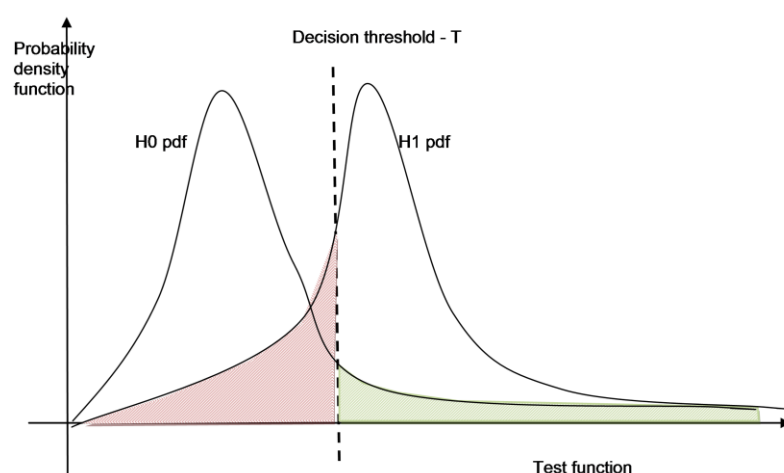


Figure 6 — Typical failure detection principle in a noisy environment

Because of the exceptional noise sample amplitude, the test function is higher than the decision threshold, as well as, generally the position error, but the protection level is not necessarily covering the positioning error.

This method of testing integrity by the unique False Alarm Rate (FAR) has two (2) main drawbacks:

- the behaviour in risky situations is not assessed;
- the duration of test is uselessly and impossibly increased (see Annex C).

The more important test case for assessing the integrity risk is to consider the H_1 hypothesis by including in the test scenario some potential feared events, susceptible to cause positioning errors higher than the acceptable limit for the given application if no integrity barrier would be inserted for the detection of that risky situation.

The test should then be repeated several times for counting the case of miss-detection events (testing function < detection threshold). The test duration get for evaluate H_1 is generally shorter than a H_0 testing and proves better the safety or liability with respect to abnormal situations.

The miss-detection corresponds to the cases where the test function is not able to detect because of a too weak impact of the situation on the test function. Since the protection level has been generally

⁶ http://www.navipedia.net/index.php/RAIM_Fundamentals

consistent to the hypothesis test, in this case, the position error is greater than the protection level and the integrity risk is well assessed. The miss-detection probability is represented on the Figure 6 by the red hachured area.

Considering the choices of the standard to avoid the introduction of the notion of alarm limit or maximal acceptable positioning error, which is depending on the application, *this kind of test (integrity risk assessment) is necessarily delayed to the application level.*

Moreover, *simulations are mandatory for that kind of situations*, introducing rare events which will likely not been encountered in field tests.

During field tests performed on the road, in particular in urban environment, a risky situation where NLOS or excessive multipath will already naturally exist, which could be considered as rare feared event for open sky applications like aeronautics. However, it is a normal environment for the road and the accuracy requirements should be naturally met in this normal environment.

In addition, integrity barriers should be tuned to face additional feared events which might increase the positioning errors beyond the expected accuracy:

- uncorrected ionospheric storms;
- interference effects.

It is mandatory for safety critical or liability critical applications to evaluate the integrity risk in such scenarios in the assessment process before a homologation/certification.

It is necessary to use simulation for the addition of special cases of measurement errors, but it is essential to make these tests in the operational environment (realistic multipath and masking situations) since the detection process has to consider adequate measurement models errors.

5.6.5 Particular case of the TTFF assessment

The TTFF assessment is also a statistical metric, but it does not rely on the positioning error, and therefore does not require a reference trajectory for its evaluation.

A preferred method for TTFF will therefore rely on field test, because of the perfect respect of the link budget of signal power which is a major parameter for the GNSS acquisition process.

Even if a first assessment of the GBPT TTFF can be phased at the 'positioning level', a non-regression of the performance should be assessed once the GBPT system will be installed on the vehicle since, for example, the quality of the supply (for the stability of the GNSS receiver clock) can impact the TTFF.

5.6.6 Fit the test methodology to the metrics purposes

The principal interest of the metrics assessment in this standard is to classify the tested receivers with regard to their abilities to meet the ITS applications requirements for finally:

- making marketable products;
- making safe ITS applications;
- authorizing liable new business solutions.

The need is not to make a scientific statistical assessment of a multi-parametric function, which becomes impossible because of the quasi infinite dimension of the variation range of its numerous parameters.

The need is to differentiate the marketable GBPT according to their ability to be embedded in one ITS application or another, the ITS application having particular needs in a given environment.

The need is also to get *a trustable metric by separating the effect of the receiver design* (the most important factor for the market competition) *from the effect of the external dependencies* (GNSS infrastructure availability, communication network availability, etc.) *to be supported by each device*, but uncontrollable by design.

The final goal is to be able to build such a table, so that an interested industrial or ITS service would be able to select the device which better meets its own requirements for operations.

Table 2 — Final goal for the classification of the GBPT (example, for each metric)

	Flat rural	Tree line road	Mountain	Peri-urban	European cities	Modern cities
GBPT A	Class 1	Class 3	Class 2	Class 2	Class 1	Class 3
GBPT B	Class 2	Class 2	Class 2	Class 2	Class 2	Class 3
...						
GBPT N	Class 2	Class 1	Class 1	Class 2	Class 2	Class 2

For obtaining that, the best mean is to compare how all the receivers behave in terms of performances metrics in exactly the same operational scenario.

In this case, the external environmental scenario is fixed, characterized only once for the attribution of the correct representation of one generic environment according to the requirements (defined in EN 16803-1:2016 subclause 8.2.3.1), and the tests of the GBPT devices gives results allowing to evaluate comparatively their designs.

Simulations could be used for that goal, but a better representation of real life is obtained if the scenario has been fixed during a field test.

A correct and sufficient test solution is then, now enabled by the new technique ‘Record and Replay’:

- select typical situations encountered in the road world under operational scenarios, varying environmental conditions (in particular flat rural, tree line road, mountainous, peri-urban, European cities, modern cities as defined in EN 16803-1), in order to get a sufficiently representation of the position accuracy statistic (maximum level 95 %);
- agree this definition of operational scenarios with the authority bodies and/or in the standard;
- capture the stimuli only once in field tests, with the ‘Record test bench’ including the means for a reference truth trajectory, by homologated laboratories (ISO/IEC 17025). Stimuli are the data inputs of the selected operational scenario (recording phase, digitalization of the GNSS signals, digitalization of the telecom signals, digitalization of the outputs of the additive sensors with ‘equivalent reference additive sensors’), validated with authority bodies and/or in the standard;
- each time one GBPT is to be tested, put the device in the ‘Replay test bench’ and to pass the standardized scenario (optionally a sample set of them can be used if the ITS service is known and does not require any environments), to acquire the GBPT outputs for each test;
- compute the metrics on the output files and report the synthetic report by attributing the classes.

More details justifying the tests facilities and their ability to well reproduce the GNSS signals data captured during the field test, as received in the real-life obstruction and multipath environment are provided in Clause 8. A very interesting feature is that, when replays are run several times, same receiver, same scenario, the dispersion of the results leading to the CDF metrics is well representative of the receiver design (measurement noises and time correlations of filters) in the given environment, and no more due to the variation of the environment parameters from one field test to another.

5.7 Recommendation for testing strategy

5.7.1 General

In this document, we will preferably tend to provide a large accessibility of a maximum of the test procedures and analysis to a large set of laboratories, whether in terms of skills, or in terms of location in Europe.

The 'Record and Replay' testing method takes place between the pure field tests and pure simulation in the frame of test facilities. It consists in recording the real-life environment RF conditions, and replaying with high fidelity this real-life RF conditions. It is thus totally applicable to the GNSS propagation environment, and has many advantages, both for technical and economic aspects.

Under conditions using 'equivalent reference additive sensors' meeting the equivalent errors models during record, stimulating the GBPT during replay by the recorded corresponding data through standardized interfaces, it could be also further extended to hybridized systems.

The technology has been recently enabled by higher and higher integration in storage capabilities and higher and higher speed of communication buses, which allows overcoming the corresponding needs or recording high data rates. One of the main advantages of this test facility is that it also reduces the cost of required tests facilities and required skills to endorse the tests realizations and results analysis.

For that reasons, we will therefore recommend as far as possible the use of replayed tests cases genuinely stored in field tests, and approved by institutional bodies, as well as the replay tool's and procedures recommendations.

The required facilities to record is of quite high cost, but could be communalized for all countries in Europe. Besides, the required facilities to replay are of lower cost. The cost of the record campaign is increased for recording in the same time sufficient information like videos, 3D scanners, reference trajectory, to enable a correct analysis of results.

The following table describes for each phases of tests and assessments encountered in the industry value chain (column) the main points of the test strategy (line):

- the kinds of tests;
- the tests objectives;
- the coverage level of the scenario;
- the main responsibilities;
- the outputs to be reported.

Table 3 — Summarized definition of tests according to the integration phase

	sensor level	integration level (GBPT)	installation level	ITS application service
kind of test	Any	record and replay for AIA static and dynamic field tests for TTFF	Static and dynamic field test	sensitivity analysis field tests replay with additive simulation for specific errors limits (integrity risk)
objectives	Functional coverage, performances assessment, robustness to environment	Standardized metrics	Non-regression after installation (TTFF as a minimum) Robustness against temperature, supply cutoff, EMI/EMC[...] as a min.	ITS application accuracy, ITS safety goals
scenarios	full coverage	Agreed sampled road use cases	(out of scope)	Agreed Sampled ITS application use cases
Test and cost commitment	sensor manufacturers	GBPT manufacturers	car manufacturers	ITS services providers
Test results commitment	Independent laboratories having the sensor specific test facilities	Independent lab having the typical electronic device test facilities	Independent ab having the typical automotive test facilities	TBD
Test quality and coverage authority	TBD	TBD	institutional bodies ruling on car safety/homologation	institutional bodies ruling on road/traffic safety/homologation
outputs	class of sensors specific performances equivalent reference sensor sensor error model	class of positioning performances equivalent reference GBPT PVT error model	installation homologation	application safety/liability homologation

5.7.2 Proposal for a homologation plan (case of complex hybridized GBPT systems considered)

Considering the proposal for solving the tests issues (subclause 5.2.3) and the value chain (subclause 5.3.1), the roles and responsibilities in the testing strategy and the corresponding phases should be allocated accordingly, as summarized in the following table:

Table 4 — ITS applications homologation/certification proposed approach

	Sensor manufacturer	GBPT on the shelves	GBPT into the car	ITS system onboard the car
Arguments summary				
General/customized purpose of products	general	road	road	customized ITS application
Integration level →cost of test	component	embedded system	high integrated system	highest level integrated system
→available skills in final positioning performance	Skills in sensors, not necessarily in positioning, except GNSS	highest in hybrid solutions and positioning	low (integration of electronic and antenna)	low for positioning
→available skills/ ITS applications like traffic, tolling, etc.	low	medium	low	highest for ITS E2E
Roles and responsibilities in the homologation process				
WHEN? (event in the industrial cycles)	new product design SW versioning HW obsolescence	upgrade versioning obsolescence management parameters tuning for applications (TBC)	GBPT installation according car models	ITS application versioning vehicle deployment national/international deployment
WHO? (in charge of testing commitment)	Black label of sensors			
		black label of GBPT (for GNSS or testable hybridized GBPT) ⁷		
			Car installation verification of black labelled GBPT	
				ITS application homologation
		instead of steps 2 and 3 for complex hybrid GBPT (if required by test complexity) collaborative responsibility simultaneous GBPT Position performance assessment and Car installation homologation		

⁷ In the sense proposed in subclause **Error! Reference source not found.** this document. See also Figure 5.

We recommend that the global homologation/certification process for ITS applications, in particular when they should fall under safety criticality or liability criticality, relies on the four (4) steps described in the Table 4 (green boxes).

However, in order not to stop innovation, in particular about hybridization or sensor fusion, and considering the potential complexity of testing on high integrated sensor fusions in the next few years, considering the lack of the corresponding integrated test facilities, not yet existing standardized protocols and tools, considering also the potential impact of the installation above the positioning performance metrics themselves, an alternative field test step, under the collaborative responsibility of the car manufacturer and of the GBPT manufacturer, and to be specifically agreed by the adequate authority (orange box) could take place (for each car installation) and serve the assessment of GBPT positioning performances according the EN 16803 standardized metrics and classes. This process, whether it is not preferred, could be used in the short-term, instead of the double step: black labellisation of the GBPT and car installation verification.

By this way, a balanced effort and responsibility sharing would consider both the involvement of the industrials in the market and their available skills for fitting the best test cases with respect to the potential combinatory of environmental conditions which limit the final positioning performances, and in consequence the ITS applications, and complexify the right assessments of the standardized metrics (statistic definition).

The responsibility of each industrial would represent:

- for a sensor manufacturer (GNSS, inertial, cameras, etc.), a black label should be necessary for each product susceptible to enter in a GBPT's integration, attesting that *tests cases covering extensively each operational environment limiting the measurements qualities and performances have recorded results*, that an 'equivalent reference sensors' or 'additive sensor model' are available for testing hybridized systems with other sensors (standard to be completed);
- for a GBPT manufacturer, a black label should be necessary *attesting that the CEN EN 16803 standardized test cases*⁸ have recorded results under the form of the standardized classification. The corresponding test cases should be *based on a selection of true representative GNSS signals and operational environments limiting the positioning qualities and performances*, using specific 'test stimuli' well representing the additive sensors in place of actual sensors; this process should be accompanied by the generic process of the qualification in environment for electronic devices (not documented in this standard – tolerance to temperature, humidity, chocks, etc.);
- for a car manufacturer, an attestation that the *GBPT installation verification* has recorded results using the on board GBPT, RF antenna and integrated inertial systems or additional sensors. Field tests using a selection of test cases covering simple trajectory patterns (lines, roundabout, acceleration/braking patterns, etc.) should attest that there is no regression, due to installation, in the GBPT positioning performances regarding the performance classes appearing in the GBPT's black label;
- for the ITS service provider, attestations that the sensitivity analysis (as standardized by EN 16803) is provided for each ITS SW version, each used GBPT, each vehicle type, as well as a minimum of demonstrations or field tests scenario representative of the particular ITS application and use cases have recorded results (for use cases refer to [8]).

Considering the focus of the ongoing standardization process, we think that it is preferable that the targeted standard should only give general orientations for this process, optionally referring to other standards (existing or to be written) but focuses only on the highlighted green box of the Table 4. Only short indications for the collaborative field tests (orange box) will be given in this technical report.

⁸ As proposed in this technical report.

For completing the process prescription with clear specifications, some homologation and certification 'advisor circulars' (out of Scope of this document) should impose the phases/steps planning, detailing what verification should be performed at each stage of manufacturing in order to meet a specific liability (or safety) level. Anyway, the content of this technical report has been driven by this line of sight.

It appears also that *other works for standardizing and harmonizing the tests protocols* (specific test commands, intermediate data acquisition), starting from sensors (GNSS, inertial, odometer, cam, etc.) up to the positioning level in the industry chain *seems to be required*.

6 Definition of the operational scenario: how to configure the tests?

6.1 General

From now, this document focuses on the tests to be performed for a 'black labialization' of the GBPT, at the integration level, out of its installation:

- 'Record and Replay' for performances evaluation: accuracy, integrity (protection level availabilities at a given integrity risk), availabilities;
- static and dynamic field tests for TTFF evaluation.

While the strategy developed in this standard recommends record and replay for AIA metrics assessment, we are conscious that, at the moment of redaction of this technical note, the current test benches, as well as devices interfaces are not meeting all the requirements for doing such kind of tests for complex hybridized systems.

The operational scenarios which are described in this Clause 6 are to be applied essentially for the data collection in fields for the "record" part of the "Record and Replay" kind of tests.

Nothing prevent to apply these scenario *in field tests for complex hybridized system*, provided that the reference trajectory is measured during the said field tests. However, we strongly warn the standardization group that *the field test results will never be perfectly reliable, never reproducible from one lab to another*, even if a huge number of field tests trials are run, mixing a great number of tests conditions (temperature, meteo, etc.).

Clause 6 will first recall the current definition of what is an operational scenario in the part 1 of the standard, then makes a proposal for defining the operational scenario to be used for recording the operational data to be replayed for the metrics assessment (accuracy, protection level and availability), and finally a proposal for the scenario to be used for the TTFF evaluation.

6.2 Preamble

As a preamble, it is important to notice that the focus of the standard is not to measure the capability of the GNSS infrastructure (Signal In Space properties and line of sight diversity), to offer positioning performances in road environments for ITS applications. If it would be the case, we should test any European cities at any hour, since the GNSS infrastructure does not offer perfectly uniform performances through location and time. But this is not the goal of the standard.

In this standard, we want to set-up the methods to measure the performances of a GNSS Based Positioning Terminal (GBPT), namely differentiate GBPTs whose quality is acceptable from GBPTs whose quality is not acceptable for road applications market (customers).

This terminal, whether in operation or during field tests, should operate in some environmental conditions, that it undergoes, as well as the systematic errors due to the GNSS infrastructure or due to the atmosphere which are not imputable to it.

These environmental conditions are, along the road operations, sometimes favourable and sometimes unfavourable to the GNSS Signal In Space properties, alternatively.

Not only those environmental conditions, individually taken, will influence the capability of the GBPT to provide all its potential in terms of AIA performances, but also their changing rates.

The goal of the standard is to characterize the exclusive part of errors imputable to the device's processing:

- for the systematic errors of the GNSS infrastructure and atmosphere:
- only the capability of the device under test to reduce some of them by additional features beyond the strict use of the GNSS infrastructure features should be characterized
- thus, the tests shall enable the evaluation of if the DUT uses or not differential services, PPP corrections, multi frequency features, calibration through additional sensors, etc.
- for the effects of the propagation channel like masking, attenuation, multipath, NLOS, fading, combination with interferers, etc.:
- only the GBPT capability to deal with this kind of operational conditions, and especially their changing rate, is of interest for the standard: is, or not, the GBPT able to avoid large multipath additional errors, avoid signal detection on NLOS during reacquisition situations, avoid divergence in Kalman filters due to inappropriate error models, etc.
- thus, the tests scenarios, to be efficient regarding these aspects, shall be as representative as possible to the use cases, even if it is of interest to separate the metrics computation per isolated kinds of environment. Indeed:
 - the road network does not offer long roads in 'rural flat' without any trees, bridge, houses' (unless rare exceptions);
 - the road user does not choose to drive 2 h under trees, then 5 h inside a 'modern urban canyon', but choose to drive from a point A (which could be for example a parking under trees in rural area at 30 min of a modern city) to a point B (which could be in the city's historic downtown) using a road which pass (just an example):
 - alternatively (for few hundreds of m) under trees, between houses of four (4) floors and open sky;
 - under a tunnel of 350 m, then immediately after a large curve, under trees again, etc.;
 - through several kilometers of suburb, with alternatively buildings of four (4) floors then two (2) floors, etc.
 - and finally a 'modern urban canyon'.
- once the record of DUT's position is performed on typical use case scenarios, it can be analysed according several filters in order to provide a metric assessment like presented in Table 2;
- for the errors exclusively imputable to the receiver, thermal noise, internal clock instabilities;
- the scenarios should enable a large exploration of the DUT behaviour;
- thus multiple on/off of the DUT should be considered in the scenarios (at least in replay) so that the RX clock aging properties could be considered;

- as well, the accelerations and jerks effects could be appropriate during the scenarios, as far as they exists in the actual use cases.

6.3 Status of definition of an operational scenario: discussions

6.3.1 General

The definition of the *operational scenario* (see EN 16803-1:2016, subclause 5.2.10) is recalled here: '*description of the conditions in which the GNSS-based road ITS system is operating and particularly affecting the GBPT*'.

The operational environment is also important to define the test conditions in which the system's performances and metrics should be assessed.

As highlighted in the standard see EN 16803-1:2016, Clause 8, three (3) sets of parameters would have to be defined in order to accurately describe an operational scenario and subsequent test cases, since they would likely impact the assessed performance metrics:

- the *set-up conditions* of the terminal and of all its sensorial organs (GNSS antenna, inertial measurement unit, odometers, cam, etc.) conditioning the sensing properties;
- the *trajectory* of the vehicle: its location in the world, and its cinematic impacting the capability to correct or filter any sensor's defaults;
- the *environmental conditions* impacting the sensing measurements.

This list gives thus a priori the first frame in which the definition of the operational scenarios should be presented for the configuration of the test cases.

This general definition applies for any kind of tests:

- in case of simulation, it defines the scenario in which the GNSS signal simulator, and other sensors simulators shall be set-up;
- in case of field test, it defines both the features in which the test bench should be assembled and the conditions in which the test bench shall run;
- in case of record and replay, it defines essentially the conditions to be used for the recording stage, like for field tests. For the replay stage, the operational scenario is fixed by the replayed data, except for what concerns the set-up conditions.

EN 16803-1:2016, subclause 8.2.1 affirms furthermore that the GNSS reference environments *shall be used to interpret test results and to compare results of tests*⁹ which are similar but executed at different places. This is the reason why the presentation of the tests results should be as proposed in Table 2, referring to the high level categories of GNSS reference environments.

6.3.2 Set-up conditions

6.3.2.1 GNSS antenna's installation

It is recognized in the standard EN 16803-1 that the location of the GNSS antenna, and the location of other sensors when hybridization is used, have an influence on the GBPT localization performances.

That means that a performance assessment of a given GBPT, performed in one installation, then with another installation would not necessarily provide the same results. Indeed, the masking of the

⁹ Not to obtain the data set collection, but to compute the metrics.

antenna caused by the vehicle itself varies from one vehicle to another, the figures of a wind shield too if the antenna is inside the vehicle. Actually that does not characterize the sensors performances per say, but its installation.

Because of that, in Clause 5, we have proposed a set of tests to be performed after the commercialization of the GBPT, once installed in the cars models, for a demonstration of an acceptable regression (if any) of the positioning performances. But we recommend evaluating the performances metrics against operational uses conditions as soon as the GBPT has been integrated by the GBPT manufacturer, in order to be classified before its commercialization.

6.3.2.2 Sensors installation (inertial unit, cameras, LIDAR, odometers, etc.)

This part is applicable only for the record and replay tests cases. Indeed, the TTFF corresponds essentially to a pure GNSS feature, since inertial data, cameras, [...] cannot initialize alone the earth-referenced positioning process.

The lever arms between sensors reference points, and/or with respect to the centre of gravity for inertial systems have to be adequately corrected in order to provide the correct and accurate position value. For example, the lever arms between the image centre of a camera, the location of the inertial measurement unit, the GNSS antenna have to be considered.

In a 'Record and Replay' kind of tests, and as far as the sensors outputs provided by reference sensors are stored for replay, the lever arms and the alignments of the sensors axes with the vehicle reference axes used in the recording installation have to be carefully calibrated and filed.

Similarly, for a replay, the values envisioned for these parameters in the final installation should be taken into account and a sensor axes frame correction should be applied to the recorded information before becoming the stimuli of the replayed tests. By default, if the parameters for the final installation are not known, it is proposed to correct the records from the filed data so that the replayed stimuli are considered to an IMU perfectly put at gravity centre and aligned with the vehicle axes.

6.3.2.3 Temperature, vibration, supply and other environmental conditions

While we recommend replay tests, performed in a lab for the GBPT performances assessment, we are conscious that other physical environmental parameters might influence the final performances in a car's installation.

This is true in particular for temperature, vibration, power supply for which the lab environment is quite particular (stable deck, ambient temperature, stabilized electrical supply, etc.).

As per GNSS antenna, the car's installation will not be considered during the performances assessment, but, once installed in a car model, a minimum of tests should be performed for a demonstration of an acceptable regression (if any) of the positioning performances.

6.3.2.4 Complementary communication services

It is important to add there the importance of the setup of the communication services which has an essential contribution to the performances of some GBPT systems:

- differential GNSS services with RTK, NRTK, PPP data for accuracy, protection level, availability metrics;
- assisted GNSS services during the TTFF field tests.

The test bench should activate these services and record their data for the record and replay and verify that A-GNSS services are useable in real time for certain TTFF field tests.

6.3.3 Trajectory/motion

Even if it was pointed out in subclause 5.7 that only a non-exhaustive combination was possible in the performance assessment, it is important and even recommended, for a good basis in the statistic computations, that various situations would be inserted in the collecting data, as they are possibly encountered in the car's operations.

When we analyse how to configure the tests, we rapidly understand how various can be the car's operations, just for trajectory and motion aspects levels, independently from the GNSS environment. With background on the positioning techniques, whether they would rely on land/space marks triangulation/ tri-lateration, or on velocity integration, it is known how this diversity can have influence on the GNSS receiver signal processing behaviour, on the hybridization process as well, and finally on the positioning accuracy and availability.

Currently, the Clause related to the trajectory in [AD1] defines it as a series of time-stamped positions, and should be described in such a way that it is possible to follow it with a test vehicle.

It is also written there (in opposition to the previous strict definition covering a series of time-stamped positions, velocity being directly derived from position) that a description of roads or streets to be taken with a general requirement in terms of maximum or minimum speed can be sufficient.

There are several comments with this rapid description before to use it as a basis for the frame of the field tests:

- This definition is currently very simple and very open so that it enables a lot of situations, favourable point, but, in consequence, put as mandatory the need to setup during each run of field tests the required means and facilities to reliably establish the reference trajectory. These facilities can be simple and low cost to setup when expected performances are of the 100 m range of magnitude for positioning errors, but are more complicated and expensive when the expected class of accuracy performance reach a better than 1m value in urban environment. This point, very unfavourable to pure field tests, is hopefully compensated by using 'Record and Replay'. Thus, effectively, as far as the 'Record and Replay' kind of test is selected for making test cases, this simple definition could be convenient. The use of replay will enable a strictly identical trajectory for repetition of tests, whatever the location of test would be.
- This definition does not give an accurate enough cinematic (just boundaries), making no recommendations about the possible dynamic, acceleration and jerk patterns. This is a real problem since the GBPT performances are impacted a lot by these features. According to the acceleration/jerk pattern, any GNSS receiver might have loss of tracking lock beyond a certain acceleration limit, either onto one or several satellite tracking channel, or onto all satellites when the clock comes beyond its specifications. This is particularly sensitive, as the devices in automotive will be low cost, therefore integrating low end receiver clocks. We recommend that some scenarios integrate some immediate braking, like found in dense traffic.
- Also, the cinematic plays a role of the utmost importance in hybridized systems, when inertial units are used to bridge the positioning availability during GNSS signal obstructions: a tunnel or under-bridge crossed with high speed or low speed with largely change the duration of use of a pure inertial measurement unit, therefore the positioning errors. We recommend that the accelerations patterns shall be part of the definition of the operational scenario, as well as the velocity patterns in high masking environments (urban tunnels/ canyons). The cinematic of the test can largely influence its results because the GNSS multipath effects have actually more severe effects when the system is quasi static (errors biases) than in high dynamic (quasi white noise, enabling filtering). Inversely, the accuracy/ integrity operational requirements should also depend upon the velocity, since the safety of life and in particular the severity of accident depends also upon the velocity. Consequently, several test cases, typically encountered in automotive real life, with various cinematic situations should be run. One of the interest of the 'Record and Replay'

kind of test is that the cinematic experienced during the record is further strictly reproduced for any replay, fixing then the corresponding parameters of the scenario.

- This definition partially recovers the environmental conditions since when you define a road, you also define its environments (existing buildings, trees, mountains, etc.) and when you define position, you define latitude, while latitude and environments are parts of the listed environmental conditions (as recalled below), in the same time, the road does not completely define the GNSS environment since the conditions can also depend upon season (tree with or without foliage, windows with glass open or closed, road with numerous or rare moving obstacles, etc.).

In the definition of the combinatory of the operational scenarios defining the tests for the metrics assessment, we recommend to separate the selection of roads (location, topology of test which naturally embed the existing GNSS environment in field tests or recording phases by the presence of buildings, forest [...], road width), and the motion or cinematic, which can be different, on a given road, according to the traffic jam.



Figure 7 — Time spent under a bridge depends on traffic jam, and impacts positioning performances

6.3.4 Environmental conditions

In the classical process of tri-lateration used in GNSS based positioning process, two differentiated factors impact the positioning errors and therefore the metrics to be assessed:

- the ranging measurement errors;
- the geometric discrimination capacity of the available measurements (geometry of satellites lines of sight).

Apart from the performances of the electronic device itself (thermal noise, clock drift), apart from the systematic errors exclusively imputable to the GNSS SIS (ODTS) and to the atmosphere (ionospheric and tropospheric delays), the first parameter is directly linked to the DUT capability to resist to the existing bad effects of the local propagation channel for providing the expected measurement:

- the expected measurement is exclusively linked to a properly powered line of sight direct path;
- the actual measurement is the fruit of diversely attenuated and delayed paths due to local reflection, refraction, diffraction.

The second parameter, which is generally adopted under the Dilution of Precision (DOP), represents the degree of diversity of the provenance of measurements in the sky (DOP value close to one (1) for a good diversity and high DOP values for a poor diversity). This diversity degree enables, or not, the good transfer of the satellite measurements towards a geographic location, with a proper differentiation between each coordinate axes of the geographic frame: with a strong value of DOP, you may confuse latitude with longitude, altitude and time, etc. Historically, DOP had a great influence in the performances because the number of satellites and the number of reception channels in the receiver was quite poor. Today, DOP is still important in road application not for the historical causes, which does not exist anymore, but because of the frequent and changing signal occultations in built areas or in mountainous areas.

In order to explore the position errors statistical laws defining the AIA metrics during the tests scenarios, it is sufficient to explore the variation of these two parameters, and their correlations, for what concerns exclusively the DUT's participation.

Therefore, it is important to explore the DOP variation resulting of the local occultations, as well as its corresponding correlation times like potentially encountered in road use cases, to explore the measurements errors due to local propagation channel, and its corresponding correlation times, and finally to explore errors due to receiver thermal noise, generally considered as white noise, but whose effects depends also on noise power with respect to useful power, and errors due to local clock drift which depends on cinematic and aging.

EN 16803-1:2016, subclause 8.1.3, defines currently in, eight (8) types of environmental conditions:

- Point 1 to 4 impact together and exclusively the geometric discrimination capacity (DOP) and, finally are redundant for the definition of field tests scenarios. Together, these parameters impact the ability of the receiver to well estimate each component of the 3D position, as well as time, and the ability to have enough redundancy in measurements axes to detect one (1), two (2) or more measurement errors. This DOP feature ('Dilution of Precision') is finally, at the GBPT level, the combination of the satellite orbitography (point 1), the latitude and longitude of constellation observation (point 2), the various obstacles occulting the radio paths (point 3 and 4). While it is essential to separate each point inside a simulation model, these conditions will be encountered directly through their combination, without a need of any distinction between them during any operational use of the GBPT, as soon as the trip (or journey) is selected on a particular road, at a given time (test – recording phase execution). During field tests or during collecting the record and replay data, natural obstacles are determined by the natural field topology, and mobile obstacles are the fruit of the chance. By selecting various enough topologies of roads and typologies of traffic jams, the combination brings itself to a various enough diversity of dilution of precision without searching the variety in constellation parameters or locations on earth (latitude longitude). The DOP time variation will even be largely faster due to occultations than due to earth-satellite motion, necessitating shorter duration of tests for more representative correlation times in positioning errors for roads applications. That is why in the proposal of operational scenario, it is not mandatory to vary the time or location on earth of the test cases. Moreover, their combination will be absolutely stored in the 'Record and Replay'.
- Point 5,6,7 impact directly and exclusively the radio propagation channel applied to the GNSS signal, and therefore the ranging measurement errors and availability. Again, while it is interesting to differentiate each of this parameters during the receiver design and validation, or during simulations of the GNSS signal, this differentiation is quite impossible during field tests, and there is actually no need for a separation of the different parameters 5,6,7 since they all impact the same parameters. It is just necessary to propose, through the variety of tests, a representative variety of propagation configurations, and especially of its usual time variation in road applications. It is why we recommend to accept the natural variation of the 5,6,7 environmental conditions during road use cases, respecting their impacted errors time correlations, rather than separate the environments in tests scenarios. We have to notice here that

intentional interference or jamming is out of scope of this document as a part of work package 2. Another point to be pointed out is that the weather conditions may have more effects above the additive communications systems (like DGNSS and A-GNSS services) than above the GNSS propagation, which is quite insensitive to humidity. For those points, we have also to take into account the foliage existence or no, depending on the seasons. For this last aspect, we recommend to make only a worst-case test in order not to increase the length of tests: end of spring-early in summer are recommended for recording the data to be replayed in order to have the densest foliage.

- Point 8 talks about ionospheric conditions, which is not imputable to the GBPT except for its capability to reduce this error by additive means. This point, impacting the accuracy metric, depends on the solar weather. Furthermore, the effect appears stronger during the day, at the highest sun, than during night. For recording the data necessary for the record and replay, we do not recommend to multiply the tests according the solar activity, or to get several times in the day. We recommend just recording the data at midday, so that the ionospheric effect will be the worse, the most time and spatially decorrelated. Worst effects could be added during the testing activities related to the integrity risk measurements in simulations (application end to end tests).

6.3.5 Synthesis on the construction of the operational scenario

The proposal included in this document relies on a pragmatic manner to get a sufficient combinatory of the test conditions, without customization to one or another final application:

- The road selection imposes the GNSS geometry and the propagation channel: it is not possible in field test to change the topology of a road or of its neighbours, so it is important to integrate in the selection of roads a variety of landscapes, and landscape changes impacting visibility and reflection/diffraction effects in the same manner than typical use cases.
- The kinds of trips can impact the cinematic, in particular the proportion and amplitude between low and high speeds, and this factor, mixed with the GNSS environments, will involve alternative best uses between inertial or local vision sensors and GNSS sensors, and consequently stimulating the hybridization systems, and various errors correlation times in the same manner than typical use cases.
- A cross between road selection and nature of trip for the car will naturally cover the range of the positioning errors (up to 95 %) by covering the major part of the parameters listed in EN 16803-1 environmental conditions with effects both on DOPS and on ranging measurements errors.
- No extreme limits of environmental parameters will be looked for, but a preference for worst cases regarding some usual parameters: thus most of the test records will be done at the end of spring and in the afternoon so that no advantageous effects of foliage and ionospheric delays could be found.

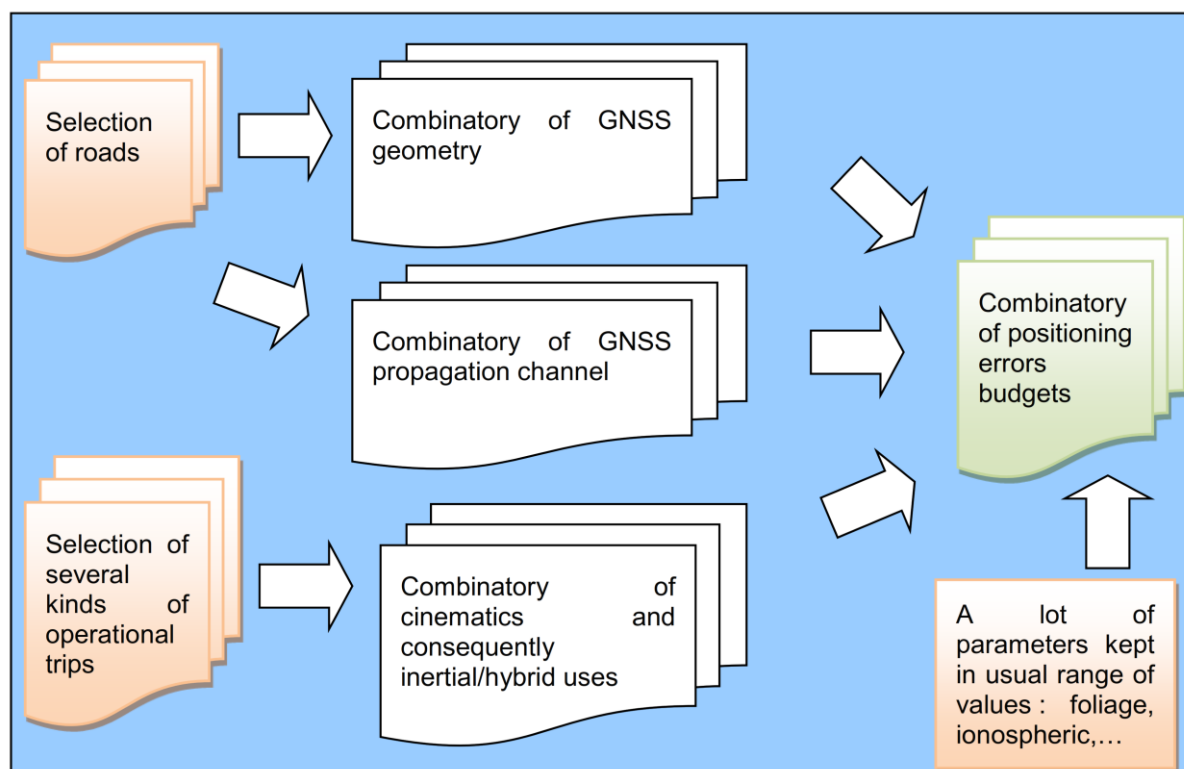


Figure 8 — Methodology to build the combinatory of operational scenarios

Once the final application is determined, the manufacturer could be authorized to restrict the operational tests to two (2) or three (3) most convenient test cases.

6.4 Descriptions of operational scenarios expected for record and replay testing

6.4.1 General

In subclause 6.4, we focus on the operational scenarios to be used in the tests for the assessment of the accuracy, integrity (protection level) and availabilities metrics.

6.4.2 Set-up conditions

As mentioned earlier, only the GNSS antenna installation will be considered. The test procedure will include two (2) phases: a 'Record and a Replay' phase.



For the record phase, the data recording is performed once on each operational scenario, and the recording has to be homologated for being replayed for any other devices. The GNSS antenna (bandwidth, omnidirectional beam, ground plane, noise figure, stability of phase centre, etc.) is not necessarily the GBPT's antenna. In contrary, the GNSS antenna characteristics and the antenna installation should be carefully selected so that they will not disturb the quality of the broadcast GNSS

signal beyond the propagation up to the installation point of the antenna: hemispheric beam, no supplemental masking, no supplemental multipath, no supplemental attenuation, etc. Furthermore the selected GNSS antenna should preferably be the common source for the reference receiver to validate the record-replay data and the RTMes (Reference trajectory Measurement system).

For the replay phase, two (2) cases would appear:

- the antenna is an external accessory to the electronic device: the replay test bench would preferably use *conducted test* with replayed GNSS signal provided through the antenna connector, etc.

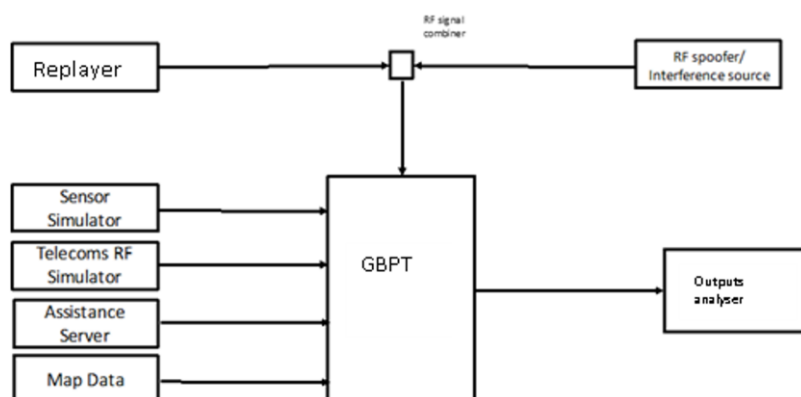


Figure 9 — Test bench for conducted replays

- the antenna is inside the electronic device GBPT: the replay test bench will perform *radiated test*, using an anechoic chamber and a realistic representation of the installation environment: replayed GNSS signal is provided at the antenna beam.

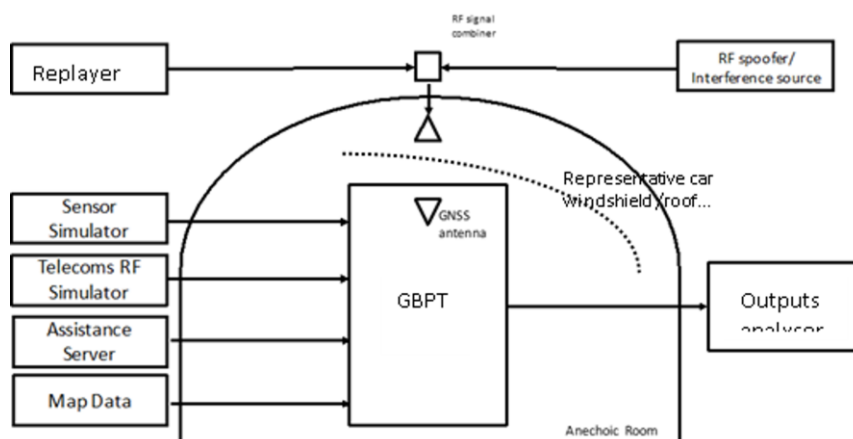


Figure 10 — Test bench for radiated replays

In this last case, if several configurations of installations (location behind the windshield, inside a suitcase, range to the roof, etc.) are envisioned for the GBPT, the performance assessment should be done by several tests with several configurations of propagation in the anechoic chamber, or a special analysis for sensitivity to installation should be provided, accompanying the tests report.

Oppositely, when conducted test is performed, the performance assessment is considered and displayed as an assessment at GBPT RF input. In this case, few field tests have to be performed after the installation in the car model in order to verify the good quality of installation (just as a non-exhaustive verification of non-regression performances).

6.4.3 Selection of roads

Concerning the trajectories to be used to cover the operational scenarios that may be typically encountered by car's applications, it could be important, to include in the operational scenario a diversity of trajectory situations regarding a number of parameters:

- Directivity of roads, linearity/ curvatures: several test cases should be differentiated covering as well long regular heading-fixed road and frequent heading changing roads, both for rural environment and in urban environments.



Figure 11 — Left: a modern organization of roads in Madrid - Right: the town centre in Toulouse

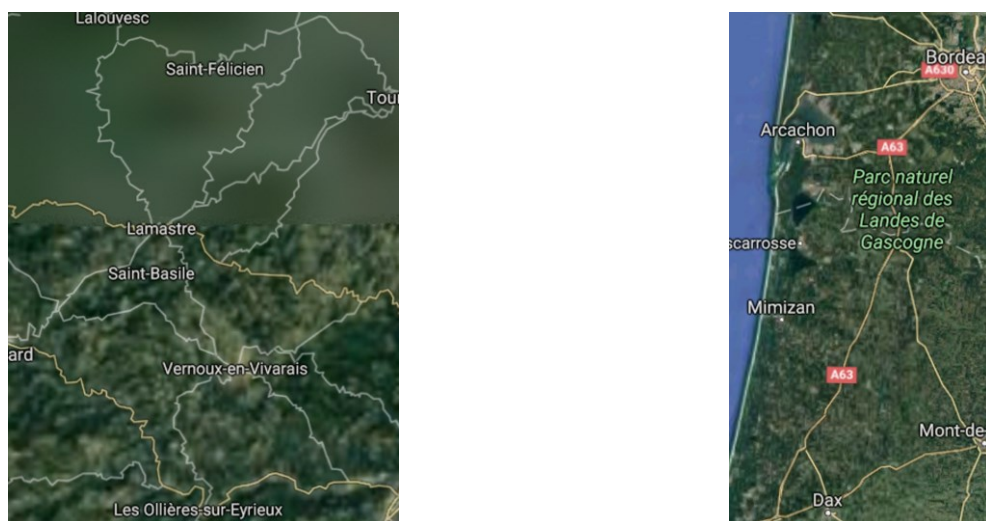


Figure 12 — Typical rural roads depending on the relief: Left: Massif Central in France - Right: Landes in France

Indeed, the variation of the masking of the satellites by the buildings along the street border can be slow for linear streets (Madrid, Landes de Gascogne examples) while it can be quite fast (for centre of Toulouse, Massif Central examples) accentuating the effect of satellite signal reacquisition time in the second case.

- Declivity of roads flat/ medium slope/long slope/ambiguous altitude: as well for vertical performances, it is important too to get a various topology between flat and mountainous.

Variety exists in the trajectory paths by crossing the two (2) features: directivity and declivity.

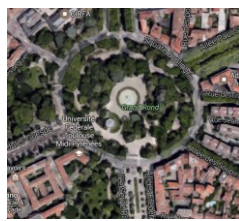
Test case/road topology	Rural Linear-fix heading (>2 km)	Rural frequent heading change	Urban linear fix heading (>1 km)	Urban frequent heading change
Flat				
Constant Slope ($\pm$)				
Ambiguous altitude				

Figure 13 — Segmentation of road's topologies

Just by having a look on the pictures presented in the previous clauses, GNSS aware eyes will identify a variety of GNSS environmental conditions as described in the EN 16803-1:2016, subclause 8.1.3:

- geometry of the GNSS satellite constellation: actually it is the combination of the open sky GNSS constellation geometry (infrastructure), depending essentially on the latitude (obviously not presented on the picture) and on the building/mountain masking;
- such roads definition would naturally include various GNSS environments with natural transitions between them (each GNSS environment is covered by at least three (3) motion profiles), and typical velocity profiles, bringing a good sensitization of the hybrid systems and of their errors correlation times and propagations behaviour.

6.4.4 Selection of kinds of trips

Accuracy, integrity and availability should be evaluated on each of the selected typical road journeys using cars.

Variety exists also in the motion dynamic characteristics. We will consider in this document five typical situations which well identify typical dynamic situations:

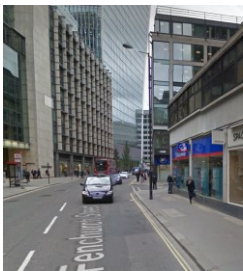
Regular long range	Professional frequent stops	Rush time	Sunday in the city	Sunday in the countryside
		 		

Figure 14 — Segmentation of trips

- ‘Regular long range’: tourism or international transport on highway from one city to another city. This typical road journey should define a velocity profile with no stop, regular long acceleration from 0 to 100 km/h for start, regular velocity to 100 km/h during a long period (no acceleration except just few velocity change of short amplitude and duration for traffic adaptation or passing vehicles), regular long deceleration for stopqwqa < ;
- ‘Professional Frequent stops’: door to door delivery, urban collective transport. This typical road journey which can apply both in urban or rural (flat or mountainous) will comprise frequent acceleration and deceleration (one each 3 min for example) from a medium speed to a stop and inversely. Stops can be present in any GNSS environment, even under a bridge;
- ‘Rush time and irregular due to traffic’: suburban to urban parking at rush time. This typical road journey is characterized by an irregular velocity, portions with a mean speed of 35 km/h, with optional stops for traffic lights as an example, and portions with stop/start for few meters and maximum speed at 15 km/h, sometimes high acceleration/decelerations and finally stop in an urban parking near high buildings. Stop for few hours then start again for the return journey, same rush time. it seems important, in particular for specific applications related to safety, to test the performances of the system with speed irregularities: sudden brakes for avoiding a collision, or to respect traffic bulks;
- ‘Sunday in the city’: suburban to urban underground parking. This typical road journey should define an suburban to urban journey, low traffic but stops due to traffic lights;
- ‘Sunday in the countryside’: small roads, regular velocity on small legs, speeds changing due to curvatures or due to urbanization. This typical journey should alternate small roads and medium traffic road in rural or mountainous environment. Minimal mean speed at 25 km/h and maximal mean speed at 75 km/h. normal traffic.

6.4.5 Crossing selected roads and trips: proposed organization of tests

Table 5 — Proposal for a list of operational scenarios

A	Regular long range	60 min	'flat rural', 'tree lined rural', 'mountainous', 'European peri-urban'	Large Highway or national way with long straight directions between large curves, relatively frequent bridges over the road, light long slopes. See Figure 15.
B	Professional frequent stops	15 min	'flat rural' and 'tree lined rural'	Typically a scholar bus in countryside: frequent change of directions, both due to curves and to navigation, essentially in flat area or with slight slopes.
C	Professional frequent stops	15 min	'mountainous' and 'tree lined rural'	Narrow roads with sharp slopes, and high maskings, etc. Typically a scholar bus in mountainous areas: starts in a pass, with isolated houses, ends in the valley
D	City bus line	15 min	'European peri-urban' and 'European urban'	Typically an urban bus line as presented in Figure 16.
E	Rush time	15 min	'European Urban' and 'European peri-urban'	High way, urban ring road with large curves, frequent bridges over the road, or short tunnels. High traffic jam
F	Rush time	15 min	'Modern city' and 'European Urban'	Narrow streets in urban canyon and larger streets with high glass buildings High traffic jam
G	Sunday in the city	15 min	'European city' and 'European peri-urban'	Typically, the same path than E but when low traffic density is observed as generally on sunday.
H	Sunday in the city	15 min	'Modern city' and 'European peri-urban'	Typically, the same path than F but when low traffic density is observed as generally on sunday.
I	Sunday in the countryside	20 min	'flat rural', 'tree lined rural', 'mean mountains'	Typically the same path than B, but longer and without stops