Testing of Rail Applications for the European Satellite Navigation System Galileo at the DLR – Coupling of Static and Dynamic Testing

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1. Abstract and Introduction

The implementation of the new European satellite navigation system Galileo will perform new options for the usage of GNSS[1] in the rail sector. Due to increasing accuracies, more reliable position information and a higher availability Galileo will become a more and more important technical solution for rail applications, especially for safety relevant applications, such as generating position information for track vacancy proving.

Before a new system is set into operation, a certification process takes place. During this process, the overall system and every module of the system have to be validated according to the technical specifications. The easiest way of validation is a static test-period in a laboratory, such as the RailSiTe® of the Institute of Transportation Systems (IFS) at the German Aerospace Center (DLR) in Braunschweig.

The RailSiTe® offers the ability to analyse, test and validate systems, subsystems and components of train control equipment. New or modified concepts – either technical or operational – can be investigated in order to achieve an optimised operation or to increase the operational safety.

The test equipment of the RailSiTe® can easily be modified for the testing and validation of navigation systems and applications. This includes the generation of positioning information provided by a GNSS such as the Galileo system. By using such a test setup, only static position information is available. For the implementation of realistic test conditions it is necessary to generate dynamic position information. This cannot be provided only by a laboratory like the RailSiTe®.

Therefore the Institute of Transportation Systems will build up a Road-Rail-Vehicle – called RailDriVE® – in the current year. The vehicle is equipped with several navigational sensors, such as a GNSS receiver, a radar sensor, an inertial platform and other sensors for the testing and evaluation of different sensor combinations.

These two laboratories – the RailSiTe® and the RailDriVE® – will be coupled for testing and validating rail applications for the Galileo system.

[1] Global Navigation Satellite System

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In the RailSiTe® the application under test will be implemented and developed test sequences will be run through. The trackside infrastructure is given virtually by the RailSiTe®. In addition, the Road-Rail-Vehicle will be driven on an existing railroad while the onboard Galileo receiver is determining the position information. The position information is sent via radio to the RailSiTe® in Braunschweig where it will be included in the testing process.

By combining the RailSiTe® and the RailDriVE® during the test of a Galileo rail application it is possible to perform laboratory tests under nearly ideal conditions with real dynamic position information.

2. The Laboratory Environment of the Institute of Transportation Systems

2.1 The RailSiTe®

The railway specific laboratory RailSiTe®[2] is the realization of a strict modular concept for railway simulation environments. Its infrastructure suits perfectly for complex investigations and research activities.

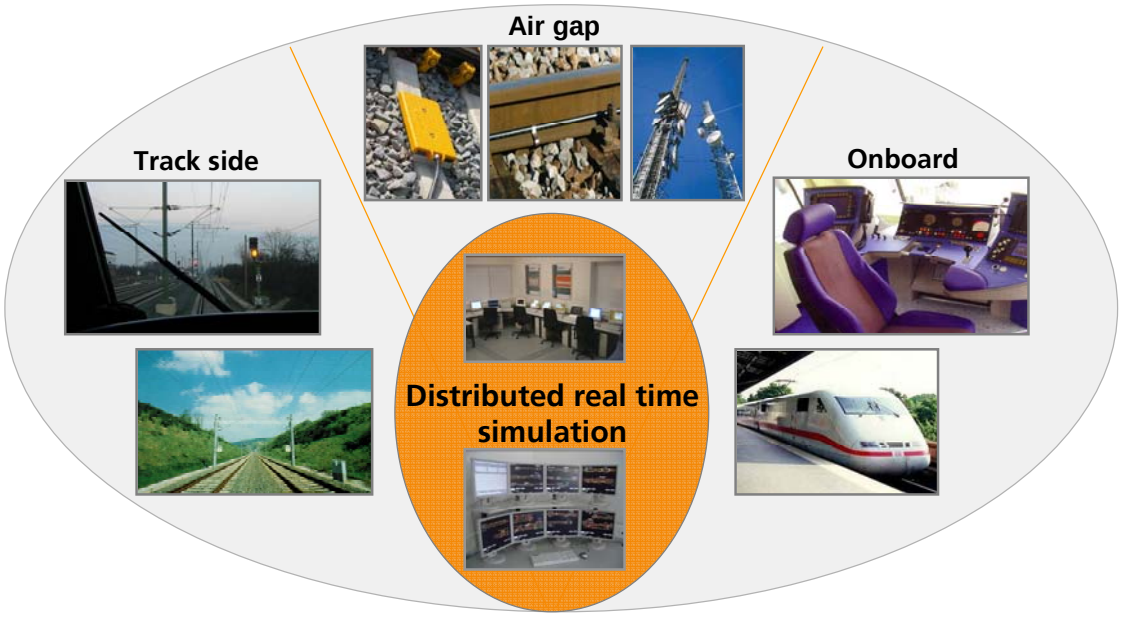

Figure 1: Architecture of the RailSiTe

The RailSiTe® offers the ability to analyze, test and validate systems, subsystems and components of train control equipment. New or modified concepts – either technical or operational – can be investigated in order to achieve an optimized operation or to increase the operational safety. Research on human factors and ergonomics is also possible due to the simulation of the complete chain from the interlocking via the trackside, the on-board system and the involved train control system up to the driver interaction at the driver's desk. The flexible concept of the lab leads to a simple extendibility for new needs. The RailSiTe® also provides the interfaces to couple real

[2] Rail Simulation and Testing

hardware with a real time test environment. The performance analysis of different concepts or technical realizations and the assessment of various migration scenarios facilitate a simplified and economic introduction of new train control systems or operational rules. The laboratory was built up and is operated independently from suppliers, railway undertakings or national authorities. Therefore it can e. g. offer a neutral platform for tests spanning different suppliers or the reference to perform interoperability and conformity tests. For the evaluation of ETCS[3] on-board equipment, there is a close cooperation with CEDEX and their laboratory in Madrid (Spain).

The Institute of Transportation Systems including the laboratory RailSiTe® is certified according to the quality standard ISO 9001:2000 and as inspection body (DIN EN 45004) to perform investigations in accordance with the TSI[4]. As a non-profit organization, the German Aerospace Center offers applied research including the use of the laboratories. Third parties can use the RailSiTe® as part of a common project with the DLR or for their own investigations. The RailSiTe® covers a broad range of applications.

The modular real-time simulation enables the adaptation to special requirements and interfaces for many needs like the institute's internal research or third parties projects. The laboratory is continuously expanding and further developing new fields of application through these internal and external projects.

Proof of Conformity and Interoperability

Due to the diversity of national train control systems in the European Union, the harmonized ERTMS[5]/ETCS standard has been developed. The goal of this new system is a seamless border crossing rail traffic within Europe and the interoperability of train control equipment of different suppliers. For the certification of ETCS on-board equipment, a test specification (subset 076) along with a description of the underlying reference architecture (subset 094) has been defined. Both subsets are part of the TSI. DLR uses this test specification for the certification of functional conformity to the system requirements specification (subset 026).

Certification processes

The tests and validations of real railway equipment like on-board units within the hardware-in-the-loop test environment RailSiTe® can be used for various certification processes, for instance, to get an independent validation of the products either as stand alone or as cross-reference tests. As the RailSiTe is compliant to subset 094 – the reference test architecture for on-board units – it offers an independent and standardized platform for the notified bodies and the signalling industries, particularly the UNISIG companies. DLR was and will be involved in the specification process in the European Community; therefore, the knowledge of specifications and the test procedures can be ensured. Furthermore, the Institute of Transportation Systems offers support for the certification process beyond the activities concerning European testing procedures and sequences, e. g. in the field of safety evaluation.

[3] European Train Control System
[4] Technical Specification of Interoperability
[5] European Rail Traffic Management System

2.2 The RailDriVE®

The RailSiTe® is a well suited environment for the testing of functionality. For some sensors or sensing principles, the simulation in a lab is possible. An example is a tacho generator used for odometry. This has been integrated in the RailSiTe® without problems. For other sensing principles like radar or GNSS it is much more complex to reach a reasonable realistic representation in the lab using simulation. At least this would result in an unreasonable high effort. Therefore a suitable extension of the principle of the RailSiTe® is a test bed which can move on real tracks and capture the data flows from real sensors in a real rail environment.

This idea resulted in the so-called RailDriVE® [6] for Rail Driving and Validation Environment. The basic vehicle is a 7.5 ton road-rail truck. This vehicle can be used as a rail vehicle as well as a road vehicle. A common software and simulation architecture has been used for both RailSiTe® and RailDriVE® to ensure a smooth interaction of both.

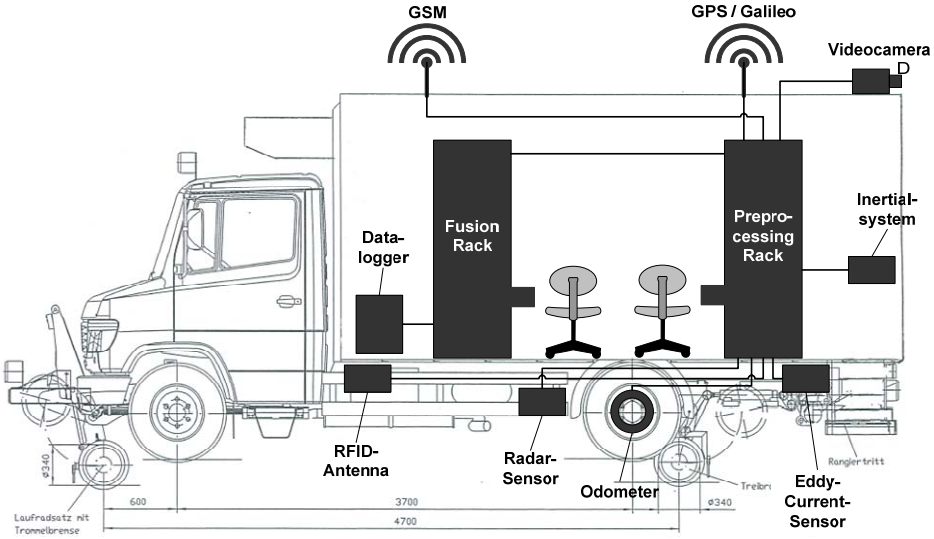

Figure 2: Equipment of the Laboratory RailDriVE®

In a first implementation stage, the RailDriVE® will be equipped with a number of sensing and communicating devices. Video cameras, an inertial navigation system and GPS can be used for both road and rail applications. An eddy current sensor and a tacho generator are rail specific and can be used on track only. A D-GPS[7] radio receiver and a D-GPS station are integrated, too. Other sensors like radar or laser scanners can be integrated in further implementation steps. A future update to the European Satellite Navigation System Galileo is already foreseen.

The current and future sensors capture different data. These need to be fused by using a suitable algorithm. Different combinations of sensors as well as variations of the processing algorithm can lead to different qualities of the result. In general, diverse sources can be used to improve the precision or the dependability of the localisation. The box of the road-railer is equipped with two working places and a number of PCs which can be used for the real-time processing as well as post-processing and visualisation of the captured data. In a further step the real-time input of the data into the RailSiTe® is planned.

[6] Rail Driving and Validation Environment
[7] Differential Global Positioning System

3. Combination RailSiTe® – RailDriVE®

Both, the RailSiTe® and the RailDriVE®, are autonomous test environments with which several, above described tests of railway equipment can be performed. The implementation of the Galileo system generates the need of certification of hardware components and of software applications. Therefore laboratory tests are mandatory.

A static laboratory like the RailSiTe® cannot perform such tests because of the lack of the possibility to generate dynamic position information. Such a laboratory can deliver on the other hand perfectly reproducible test conditions, which are needed for certification processes. On the contrary a mobile laboratory like the RailDriVE® is not able to perform tests that are reproducible though dynamic position information is available.

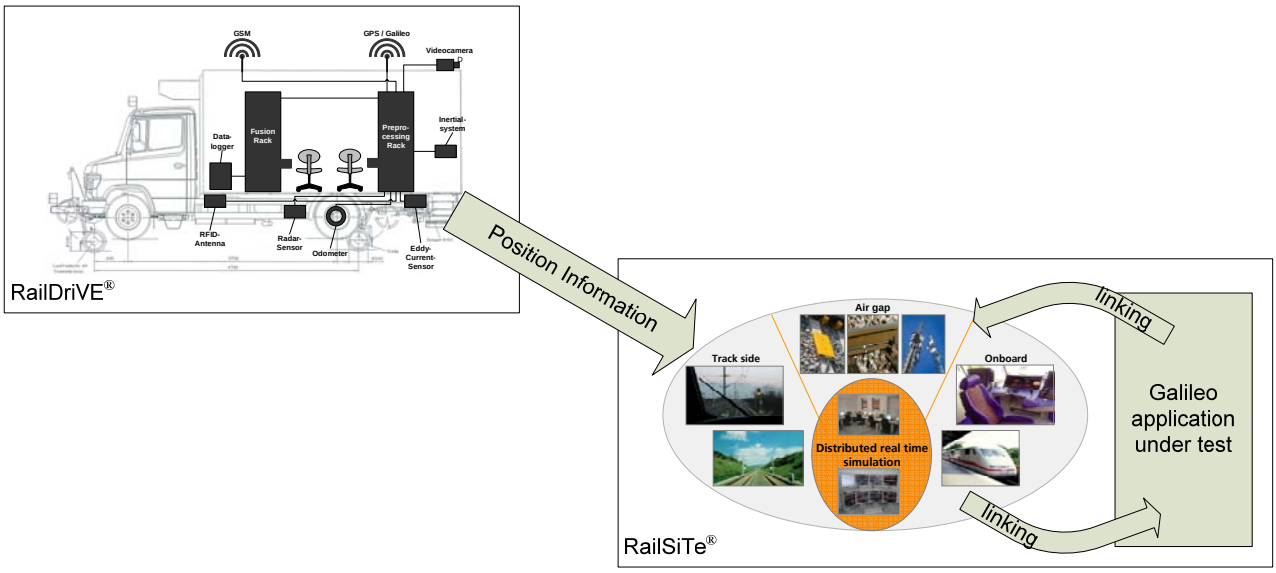

Figure 3: Equipment setup for application tests

Because of these features of static and mobile laboratory equipments, the idea is born to couple these two to one in case of performing certification tests of applications and hardware components. By coupling the two laboratories different applications of the Galileo system for the railways can be tested. For this, the application which should be tested will be implemented in the RailSiTe® only in software or as the full application including the necessary specific hardware modules. In Figure 3 the equipment setup for those application tests can be seen schematically.

After the implementation of the application under test in the environment of the RailSiTe®, the RailDriVE® will be set on an existing rail track with standard gauge running there, generating position information by receiving Galileo signals. The position information will be sent via radio link from the RailDriVE® to the RailSiTe® at the Institute of Transportation Systems in Braunschweig. If necessary, the position information can be converted in any format required by the application under test still in the RailDriVE®.

In parallel the RailSiTe® is virtually running a train over the same track as the RailDriVE® with equal vehicle dynamics. In the RailSiTe® the track is saved as a Node-Edge-Model, with detailed position information linked to every node, momentarily as track kilometre information; in the medium term the linking of GNSS position information will be implemented.

By receiving the position information sent from the RailDriVE® the Galileo application under test can be validated. Several features of the applications can be tested, like the reaction of the application and the time to alarm in the case of

- divergences between real and estimated position of the vehicle caused by shading or mirroring,
- faulty integrity of the signal in space,
- loss of the signal in space or
- an insufficient number of satellites.

The positioning information generated by the RailDriVE® and sent to the laboratory in Braunschweig can be saved in the RailSiTe®. Further tests can be performed, where generic test sequences for the certification process of different applications pass through.

These tests can be conducted under ideal laboratory conditions with real dynamic position information and Galileo signals. So the compatibility of the application with the Galileo specifications and regulations can be analysed and validated.

4. Conclusion

In the next years the new European satellite navigation system Galileo will be implemented and the operation of the system will start. For every application using Galileo it must be certified that the required specifications are fulfilled by the hard- and software. Such certification processes have to take place in special test environments where ideal test conditions of a static laboratory combined with the generation of dynamic position information is available.

These conditions will become present in the Institute of Transportation Systems of the German Aerospace Center in Braunschweig, where the RailSiTe® – a specific test laboratory for railway technology – will be coupled with the RailDriVE® – a special road-rail vehicle equipped for navigational tests with several positioning sensors, such as GNSS.

By combining a static and a dynamic laboratory, like the RailSiTe® and the RailDriVE® respectively, test conditions can be performed, where on the one hand the ideal conditions for reproducible, static laboratory tests and on the other hand the real dynamic position information necessary for navigational tests can be offered. The dynamic position information will be sent online to the RailSiTe® in Braunschweig while the RailDriVE® runs over any track with standard gauge.

The test equipment can be used for validation and certification of different railway applications using the new Galileo system. First attempts will take place in the second half of this year by running the RailDriVE® on tracks in and near Braunschweig.