CLUG 2 - Test Trains and Measurement System

WP5 – Integration & Testing (including Site Demonstrator)

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INTRODCTION

As part of the activity of CLUG 2.0 **WP5 "Integration & Testing (including Site Demonstrator)"**activity, the CLUG 2 project partners are developing, testing and analysing different technologies for a future positioning system, which shall generate much more accurate, safe train position and speed, as well as other related data, such as acceleration, attitude, etc. Core principle of the system is the combination of data from multiple, supplementary sensor technologies, including GNSS, as well as from a track map with advanced fusion algorithms.

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While the development of these fusion algorithms is largely being performed in the laboratory by offline data processing, the input data from the different sensors is field data, which is being recorded on two trains operating the true railway environment.

This article will provide an insight of the measurement system deployed in Switzerland to acquire the necessary filed data from the different sensors to perform the offline processing in the laboratory.

Test Trains

The trains used in the WP5 for field data collection from the different sensors are provided and operated by Swiss Federal Railway SBB on different lines on their network.

Each of the trains is equipped with a nearly identical sensor suite. Data from these sensors is being recorded in a time synchronised way, so that it can later be used in the offline sensor fusion. All data is being recorded with reference to UTC (Universal Time Coordinated), and is then being converted into a common data format for further processing.

The two trains are being operated in commercial service to collect data in as many different environments, under all possible weather conditions and under as many operational scenarios as possible. To also cover rare and extreme environmental and operational cases, dedicated test runs are also being performed outside commercial operation.

Test Train – Domino

A Domino train is being used for raw data collection in more rural areas in Switzerland, where they operate in local and regional services. The Domino trains were originally produced between 1984 and 1996 and have been refurbished and significantly upgraded between 2008 and 2013. The trains consist of a power car (RBDe 560 216 on the test train), between one and three coaches and a control cab car.

Figure 1: Test Train in Switzerland

The Domino power car was selected as it has already been used in the STARS and the CLUG projects for similar work. Most of the equipment required for CLUG 2 has already been installed as part of these projects. While some equipment has been upgraded for CLUG 2, and some additional sensors have been installed, the most time consuming and complex elements, for which specific approvals are necessary, could be reused. This made it possible to start collecting data much earlier than if a new vehicle had to be equipped, and also significantly reduced cost.

A number of reasons led to the initial selection of the Domino power car as test vehicle in the frame of the STARS project. These reasons also apply for valid for the CLUG projects. First, the train is equipped with ETCS (European Train Control System), which provides access to balise and tacho data required for generating ground truth data. Being equipped with ETCS also allows the train to operate on any line in Switzerland. The Domino power car also has a baggage compartment, which is not used operationally anymore. This provides sufficient space for installing the measurement equipment and makes it possible to attended measurements even during commercial operation of the train, without interfering with or disturbing the driver or the passengers. Typically, however, measurements are performed via remote access to the measurement system through the public 4G/5G network. Several other reasons also make the Domino an ideal measurement platform:

- There is a larger fleet of identical trains which rotate between different services, resulting in the train operating over many different lines, in different environments and in different types of services.
- Thanks to the fleet size it is also possible to take the train out of commercial service for some time to perform dedicated measurement trips.
- The GNSS (Global Navigation Satellite System) multiband antenna is installed on top of the power car, which generates electromagnetic interferences similar to a locomotive, providing a more realistic environment for testing GNSS than e.g., on a passenger coach.
- Due to its older design, the Domino power car also provides a fairly challenging environment for other sensors, such as IMUs (Inertial Measurement Unit) and OPGs (Optical Pulse Generator).

Test Train – Re 450

An Re 450 locomotive is also being used for raw data collection. Re 450 locomotives are part of double decker trains with the designation DPZ (Doppelstock Pendelzug), of which 115 were originally produced between 1989 and 1997 for the S-Bahn of Zurich. The DPZ trains consist of a power car (Re 450 059 on the test train), two coaches and a control cab car.

Figure 2: Re450 Test train in Switzerland

The DPZ trains have been refurbished and significantly upgraded between 2011 and 2018. The Re450 locomotive was selected mainly for two reasons. Firstly, like the Domino, it contains a baggage compartment, which again provides ample space for installing the test equipment. More important however, the Re450 locomotives, respectively the DPZ trains, operate in a much more urban environment than the Domino trains. Combined with the Domino, this significantly expands the environments, in which data can be collected.

Test Tracks

GNSS and other sensors used in CLUG 2 are significantly impacted by environmental conditions. It is therefore essential to collect data in different environments, which is not possible if tests are only being performed on a single, dedicated test track.

Data collection, and mostly data processing and analysis however also require absolute position references, as well as highly accurate, GNSS referenced track data, which are easier to obtain for a single, dedicated test track than for multiple, or even all tracks of a network.

In Switzerland, the entire standard gauge rail network has recently been converted to ETCS Level 1, or is already equipped with ETCS Level 2, providing Eurobalises which can be used as absolute position references everywhere on the network. Also, georeferenced track data of surveyor quality is available for the entire network, as SBB maintains a respective database. These two conditions make it possible to collect data and to produce ground truth for any line in Switzerland, rather than for specifically prepared test tracks only. The Domino train is stationed in Biel/Bienne. It operates mostly in the more rural area between Biel/Bienne and Lausanne, as well as into the Jura mountains. It however sometimes also operates as far as Brig in the alps, and even to Domodossola in Italy. .

The Re450 is stationed in Winterthur and operates on the entire S-Bahn network of Zurich, of which some lines extend 80 km or more from the city and even reach Singen and Waldshut in southern

Germany or some stations located in the alps. The S-Bahn network also contains several long tunnels, as well as multiple underground stations.

Using these two test trains in their respective areas of operation, supplemented by some dedicated test runs, we can collect raw data in CLUG 2 in probably all types of environments in Switzerland, which are probably also representative for most lines in Europe.

Sensors

Types of Sensors

In the CLUG 2 project it was agreed to record data for sensor fusion from the following types of sensors:

- GNSS receivers
- IMUs
- Speed sensors
- Eurobalise
- Track Map
- Weather Data*
- EGNOS SF*
- EGNOS DFMC (post data via Airbus)**
- EGNOS DFMC+PR+PV (post data via Airbus)**

*) EGNOS SF by EDAS and weather data are available in real time, but can also be downloaded offline.

**) EGNOS DFMC and EGNOS DFMC+PR+PV data are currently (at the time of CLUG2 project) only generated offline by an Airbus emulator

For GNSS, IMU and speed data multiple sensors are being used, representing different technologies, respectively qualities. This will allow the project to analyse the impact of the sensor quality on the calculated PVT, PL and other data. The following, different types are being used:

- For GNSS: high quality and low-cost types
- For IMU: MEMS (micro-electromechanical system) and ring-laser types
- For speed sensor: Wheel tachometers, radars and optical sensors

In addition, balise data and data from a high end GNSS/INS system is also being recorded for ground truth generation.

Finally, some additional data is also being recorded for the purpose of performance analysis and benchmarking. Collecting this data is not mandatory, it will however permit a more detailed performance analysis, if available. This data includes:

- Weather data, to analyse the impact on performance and sensor behavior
- Pictures or videos taken with a camera from the cab onto the track ahead, to help identifying specific environmental cases which impact performance
- Time and name of stations and locations passed, to perform statistical analysis
- PVT and PL data from reference systems for benchmarking

Measurement Setup – Example Re450

The figure below shows the setup of the data collection equipment used on the Re450:

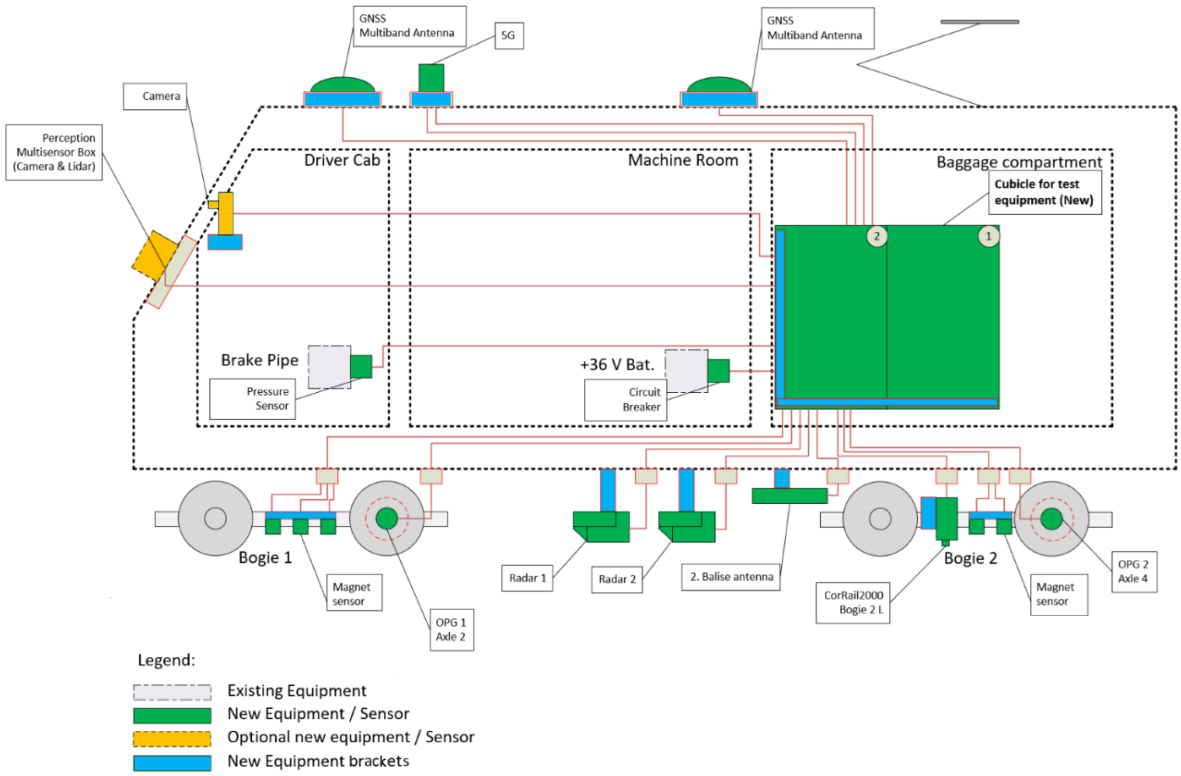

Figure 3: Overview of the data collection system and sensors - Re450

Sensor data is being recorded with a measurement system from National Instruments, which ensures that a high level of time synchronicity is achieved. This system generates separate data files for each sensor, for further processing

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