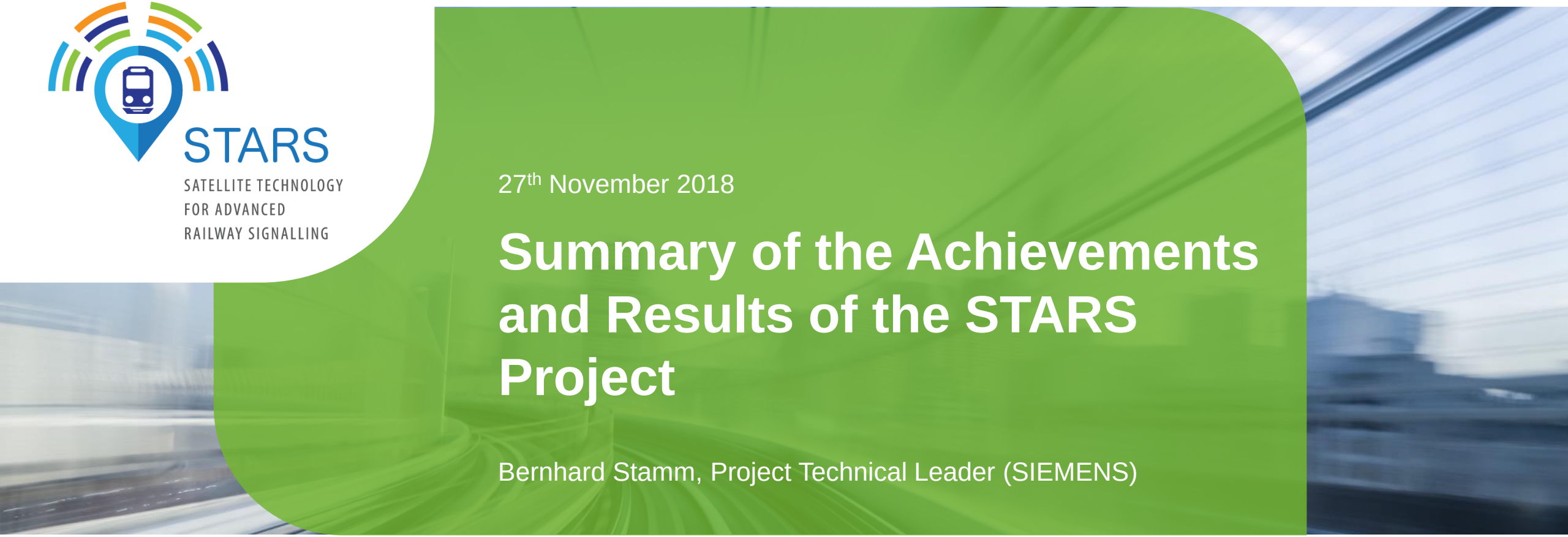
STARS

SATELLITE TECHNOLOGY FOR ADVANCED RAILWAY SIGNALLING



27th November 2018

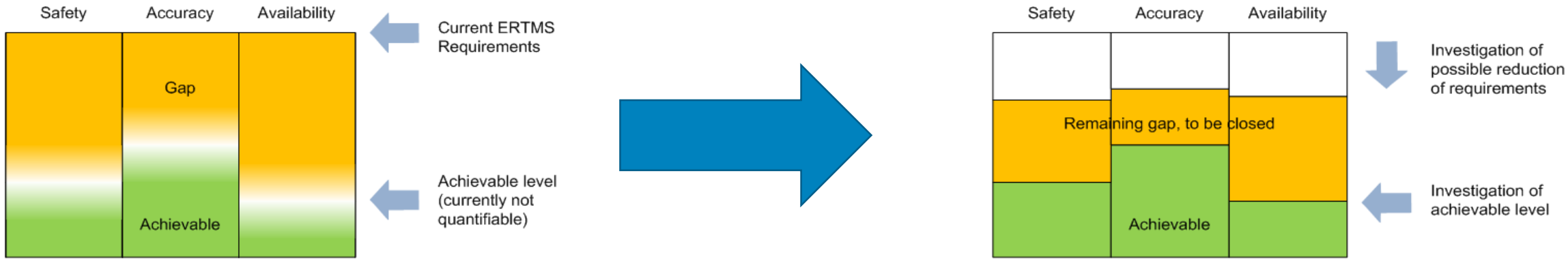
Summary of the Achievements and Results of the STARS Project

Bernhard Stamm, Project Technical Leader (SIEMENS)

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 687414

Objectives of the STARS Project

- When proposed in 2015 the main focus of STARS was to understand the achievable performance of GNSS in the railway environment, especially in regards to which local conditions impact the performance, and to which extent.
- The focus was on safety critical applications, especially with the European Train Control System ETCS.
- The goals of the project were to be able to predict performance, and to understand what additional measures are required towards an application in ETCS.



Execution of the STARS Project

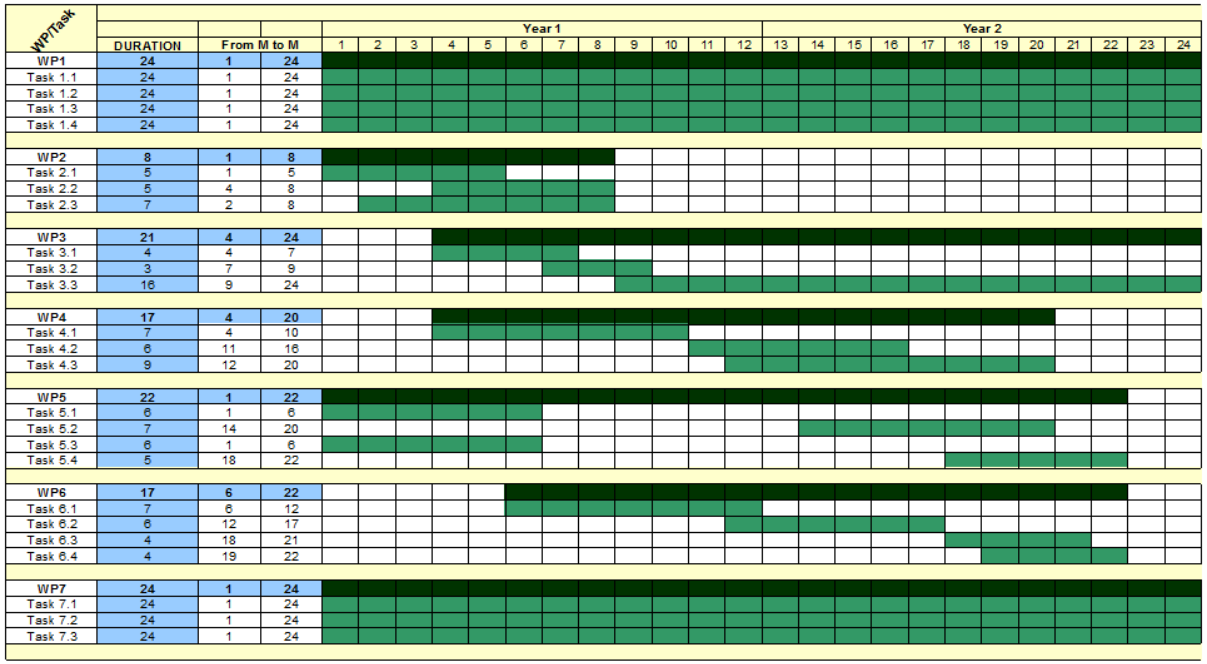
To achieve these high level objectives, the following work plan was defined:

- Develop an universal approach to perform GNSS measurements in the railway environment (WP2)
- Perform extensive field measurements in different environment to collect high quality raw data for further analysis, supported by generating a ground truth, against which performance can be analysed (WP3)
- Analyse the collected data to correlate it to the environment, with the aim of predicting the performance based on environmental characteristics (WP4)
- Investigate the possible contribution of EGNOS, and the necessary refinements to EGNOS to make it applicable for safety critical railway applications (WP5)
- Perform a Cost – Benefit analysis to understand the benefits crated by applying GNSS in safety critical railway applications (WP6)

Challenges of the STARS Project

Already when we proposed the project we listed a number of challenges we might face:

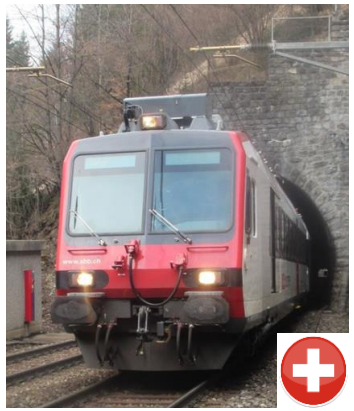
- **Tight Schedule**, with many work packages directly depending on each other
- Dependence of some work packages on **External Inputs** (acquisition of equipment, installation of equipment on trains and access to data for generating a ground truth)
- **Safety Approvals**, which are required but can only be obtained with support form train operators and safety authorities



Challenges of the STARS Project

The predicted challenges did indeed occur:

- The project experienced some delays, especially in work package 3, which delayed the delivery of data, which then had an impact on the data analysis in work packages 4 and 5.
- As a consequence the project had to ask for an extensions. Combined with a request for a further extension from GSA the project finally ended with a delay of 10 months.
- Key issues causing the delay were the procurement of equipment, the on-board installation and some safety approvals.
- Not all sites were impacted to the same extent, as e.g. the one in Italy had been used in previous projects, and therefore only required some upgrades to the on-board installation, where else the ones in the Czech Republic and in Switzerland were new installations.



Challenges of the STARS Project, Czech Republic

For the Czech installation the certification process for the installation of the sensors, which were required to generate ground truth, was more complex than expected:

- Odometry sensors had to be installed underneath the train, as it did not provide high quality odometry information.
- A special antenna to read RF-ID tags also had to be installed underneath the train, as no absolute references such as Eurobalises existed on the test track.

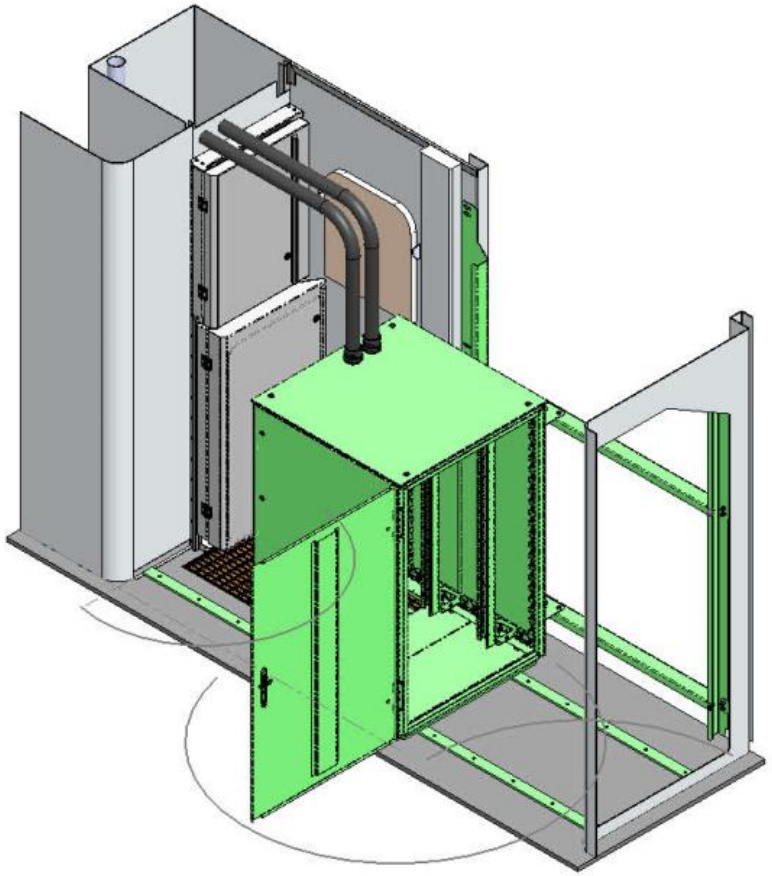
These issues led to significant certification work, which took longer than expected.

Challenges of the STARS Project, Switzerland

For the Swiss installation two major issues were not foreseen:

- The cabinet installed in the train had to be proven to withstand a 5 g impact without getting loose, potentially creating a hazard for staff and passengers.
- The customer required that only antennas are used which have been tested to withstand 15 kV / 16.7 Hz AC to prevent stray voltage entering the train in case the antenna gets in contact with the overhead wire.

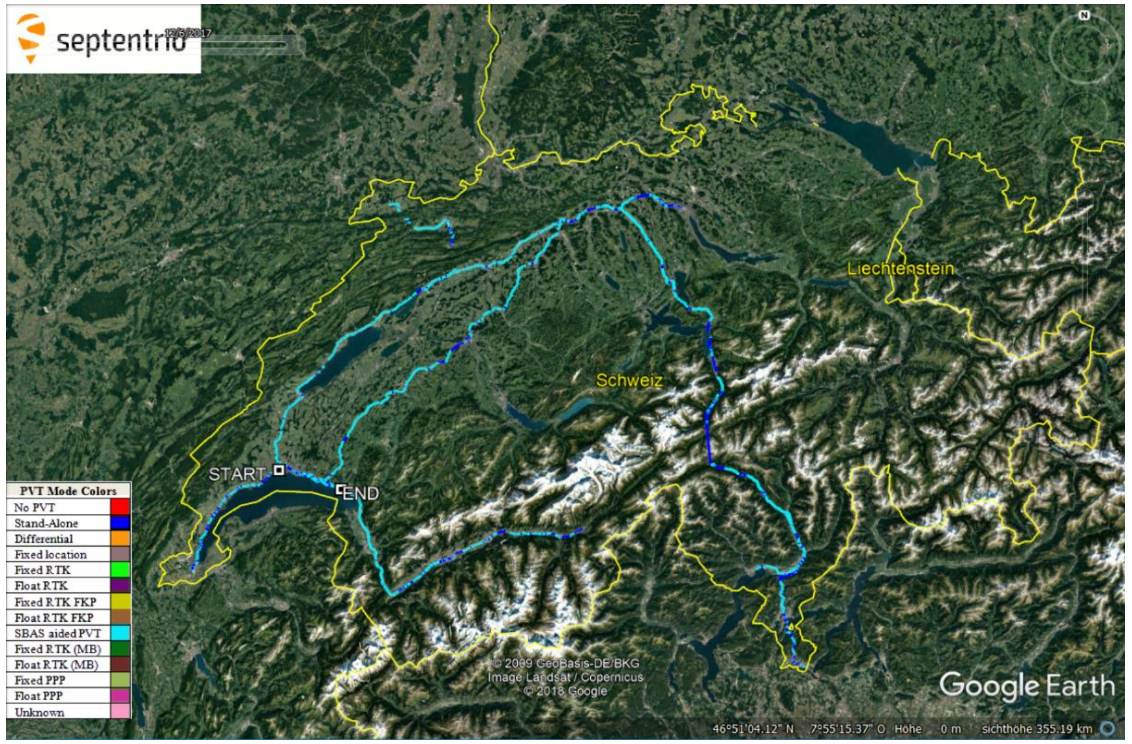
These issues led to delays, as a fixture for the cabinet designed and manufactured and a multi band antenna had to be found which complies with SBB requirements, of which there is only one on the market.



Challenges of the STARS Project, Switzerland

Finally, the generation of Ground Truth data for Switzerland proved more complex than expected:

- The Siemens test site was originally planned to be located in Germany, but was shifted to Switzerland for a number or reasons, on being that testing in a more diverse and challenging environment was possible.
- The Swiss test train however operated not only on a single test track, but on many different lines (more than 1000 km).

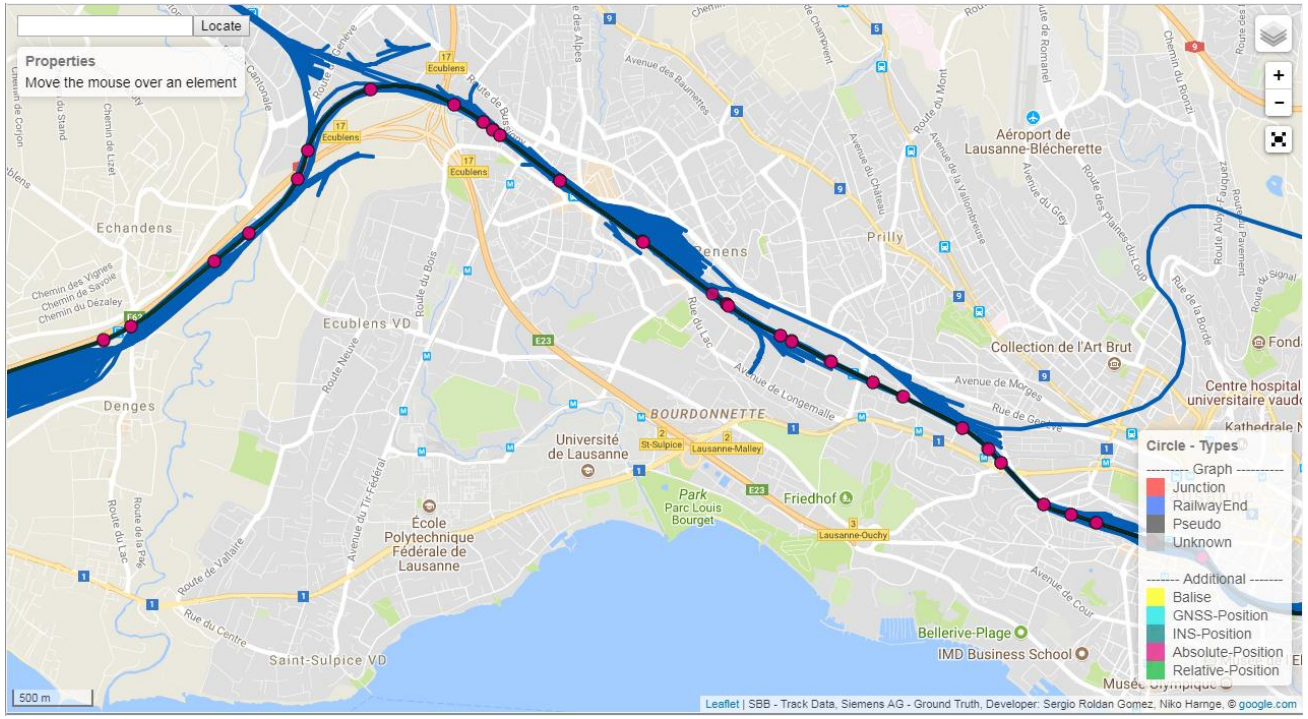


This was only possible thanks to access to accurate track data and the position of all balises on the network, but special tools had to be developed to generate Ground Truth data as the path between balises was not always unambiguous.

Challenges of the STARS Project, Switzerland

During each trip the measurement system records not only GNSS data, but also the balises passed as well as odometry data.

From this the true position of the train has been produced for any given time (for STARS in 100 ms intervals) by deriving the path taken between recorded balises (absolute positions), interpolating by using odometry data, and then mapping locations to the GNSS referenced track data.



Manual post processing was however required for each trip recorded, as the path between balises was not always unambiguous and some track data errors were found.

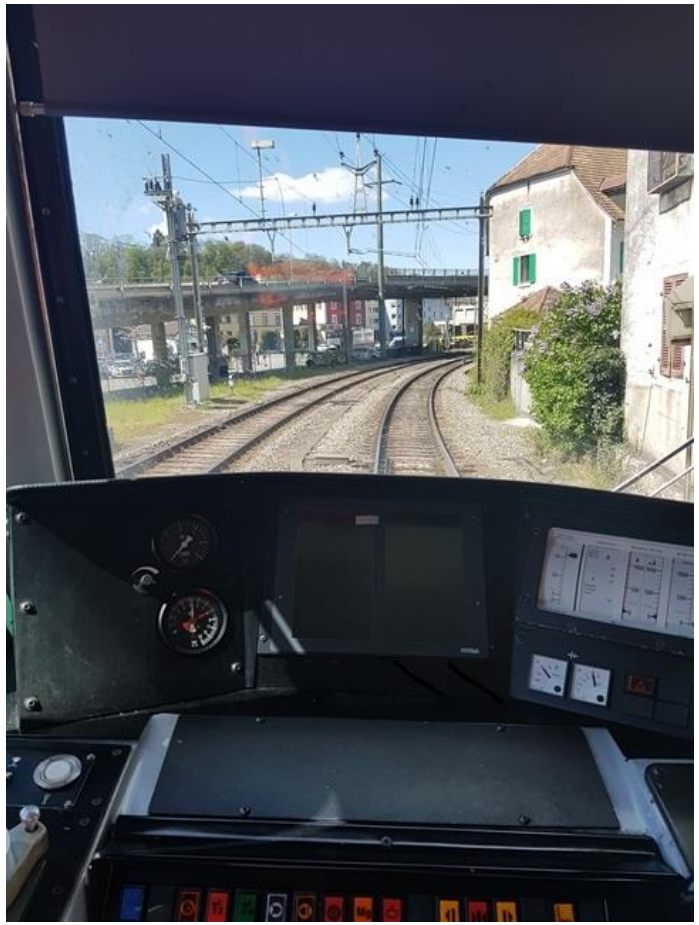
Challenges of the STARS Project

As mentioned, these issues led to some delays in the project, they did however not impact the results achieved.

The only issue we experienced in the project, which led to an amendment beyond simple shift of dates were legal issues with performing a cost-benefit analysis.

Our lawyers were strictly opposing the concept of generating a cost-benefit analysis which required the sharing of cost figures, as this can be seen as an attempt to fix prices. European law explicitly forbids even the simple sharing of cost or price figures, such as the price for a balise, but without such figures the originally planned cost-benefit analysis could not be procuded.

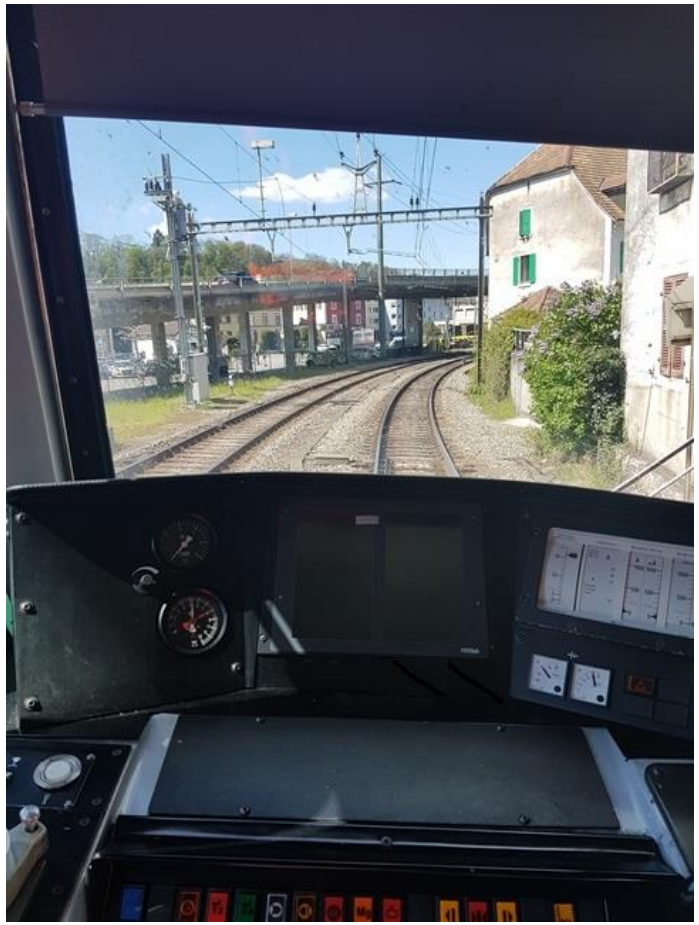
As a result we agreed with GSA on a change of the content of the WP6, which we sill see later.



Overall Achievements and Results of the STARS Project

The overall results achieved by the STARS project can be summarized as follows:

- All deliverables have been produced, with so far only minor questions from the independent reviewers. The last ones are in their final approval and will be delivered still in November.
- A very good understanding of the railway environment has been achieved, and the environmental conditions which impact GNSS performance identified and their impact quantified.
- It could be confirmed that GNSS can indeed generate accurate position information in many places on railway lines.
- It has however also been shown that, except in the most GNSS friendly environment, additional measures will be required to achieve accurate, safe and available train positioning.



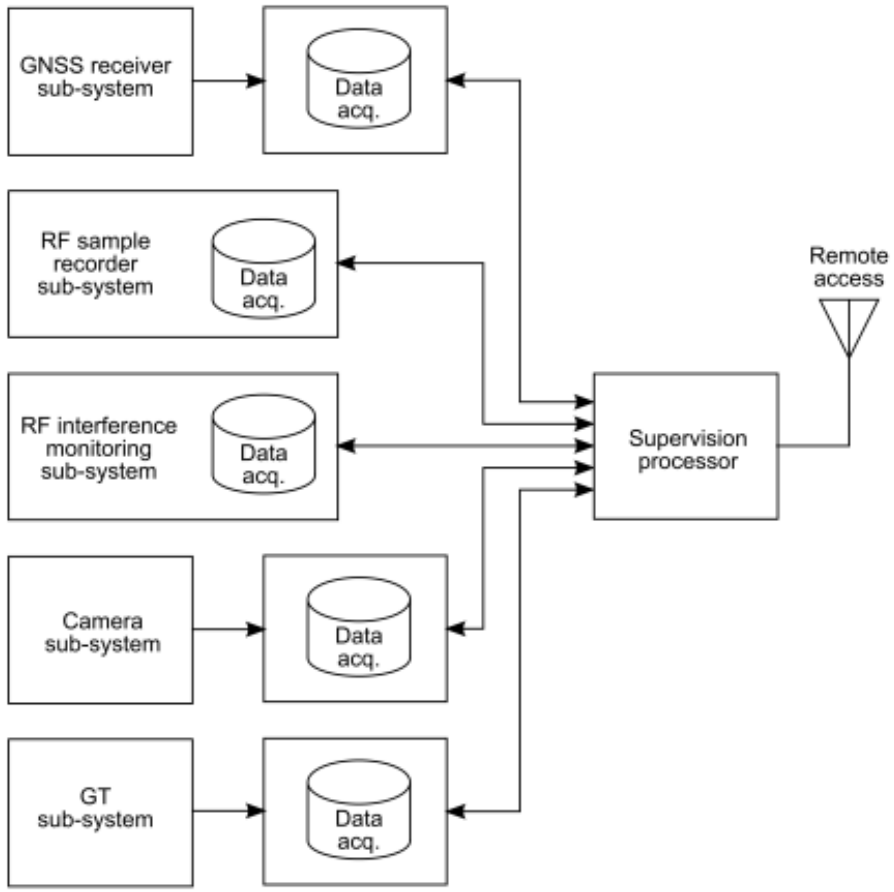
Achievements and Results of the STARS Project, WP2

Detailed specifications and procedures have been developed to perform measurements:

- By selecting the right data and parameters to be measured
- By specifying how measurements are to be executed In a uniform, standardized way across the different sites

The focus has been to ensure that high quality raw data will be collected by different companies, in different countries and on different trains, which will lead to comparable results when being analysed.

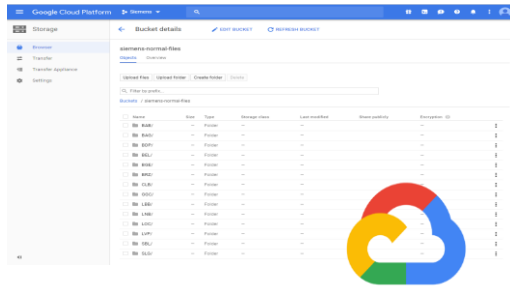
WP2 also identified potential railway lines, on which measurements can be performed.



Achievements and Results of the STARS Project, WP3

The measurement campaign has achieved the following results:

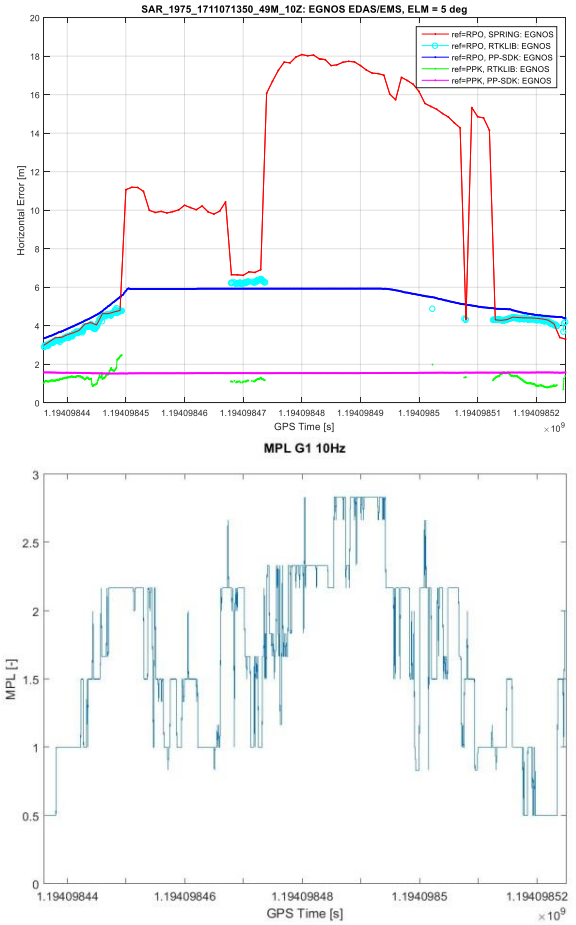
- The measurement equipment has been installed on trains in the three countries, and the necessary approvals have been obtained.
- A lot of measurements have been performed, and significant amounts of high quality GNSS raw data collected in diverse environments.
- Ground Truth data has been produced for the test trips, to be used as reference for performance analysis.
- The collected data, as well as the Ground Truth data have been pre-processed to bring them into uniform formats, allowing semi-automated data processing.
- The collected data has been stored using standardized file naming and in a harmonized structure to the jointly used cloud storage for analysis, but also for possible future use.



Achievements and Results of the STARS Project, WP4

The results of Work Package 4 can be summarized as follows:

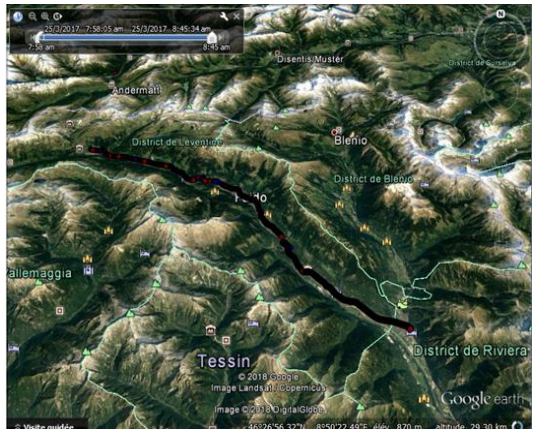
- It has produced the guidelines for data pre-process and sorting, to allow an efficient analysis of large volumes of data.
- It has analysed the recorded data using a variety of techniques, many of which had to be developed as part of the work package.
- The respective algorithms and tools have also been stored in the cloud for possible future use.
- The impact of different environmental influences on GNSS has been qualified and quantified.
- GNSS performance degradation has been correlated to the presence of environmental influences, which can be used to predict GNSS performance



Achievements and Results of the STARS Project, WP5

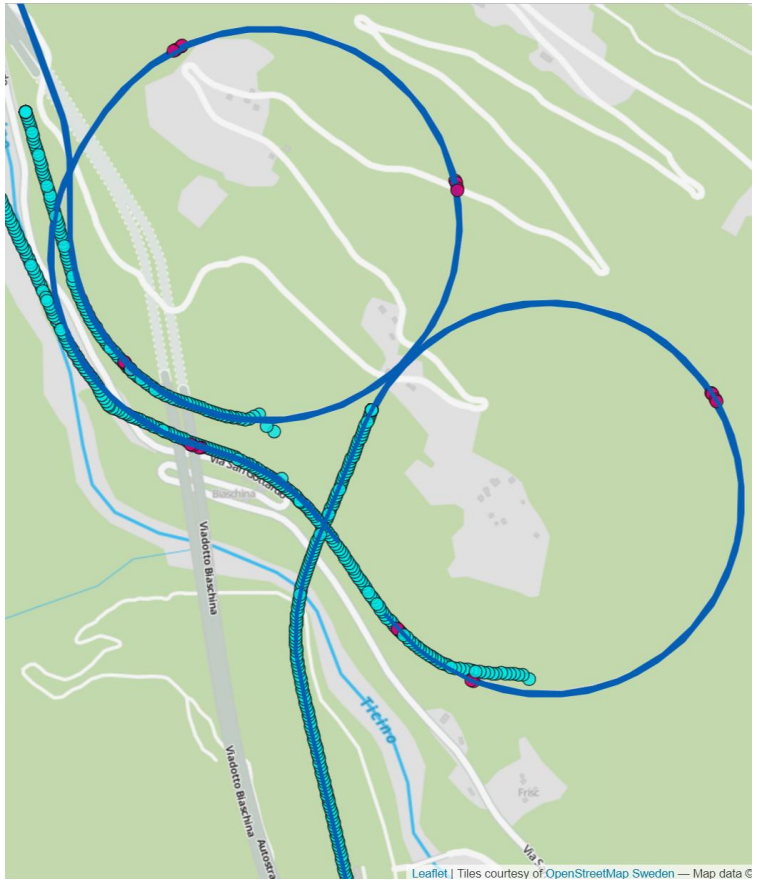
The Results achieved by Work Package 5 can be summarised as follows:

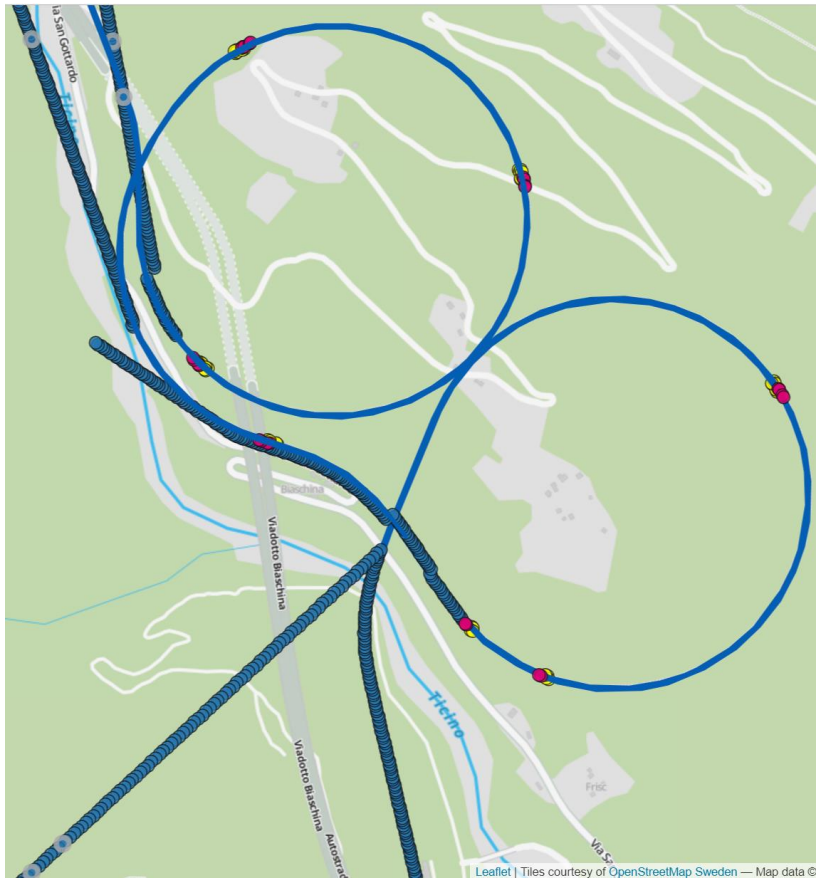
- Local effects which significantly degrade performance have been analysed, covering urban an mountainous environments, but also forests.
- It has been shown that current receiver algorithms need to be improved to cope with the railway environment, as the true error is not always bound by the protection level algorithm.
- The performance of EGNOS in the railway environment has been analysed, and has been shown that using EGNOS from geostationary satellites is not practical.
- A proposal for the evolution of EGNOS for railway applications has been produced, which overcomes the limitations identified.



Achievements and Results of the STARS Project, WP5

Comparison of low cost receiver with certified aviation receiver:

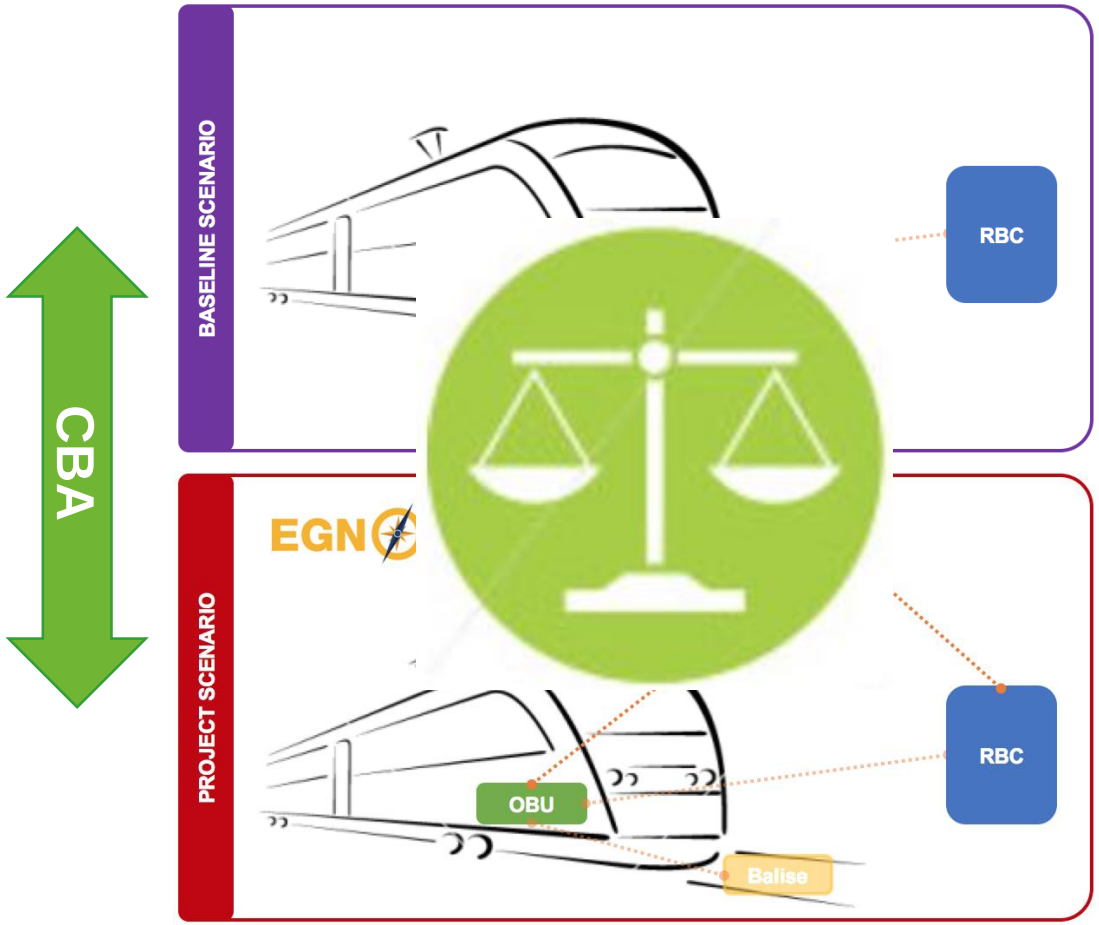




Achievements and Results of the STARS Project, WP6

Producing the economical analysis has revealed a major issue, which led to the only significant amendment in the project.

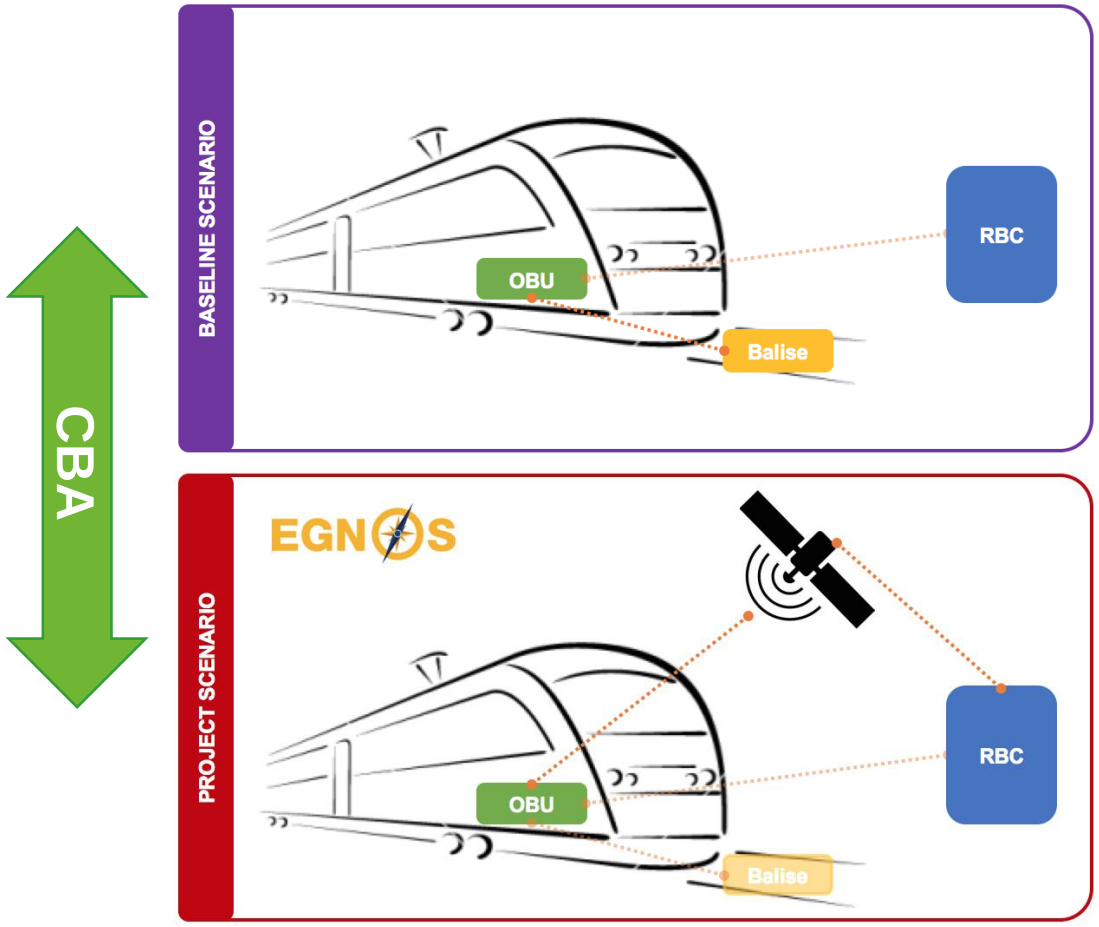
- Performing an analysis as originally requested created legal issues, as cost assumptions would have to be made jointly between suppliers, which could have been interpreted as an attempt to agree on, or even fix prices.
- A procedure therefore had to be found first by which cost assumptions and subsequent calculations were done in a way which is compliant with European Anti Trust laws.



Achievements and Results of the STARS Project, WP6

After redefining the scope, the following Results have been achieved:

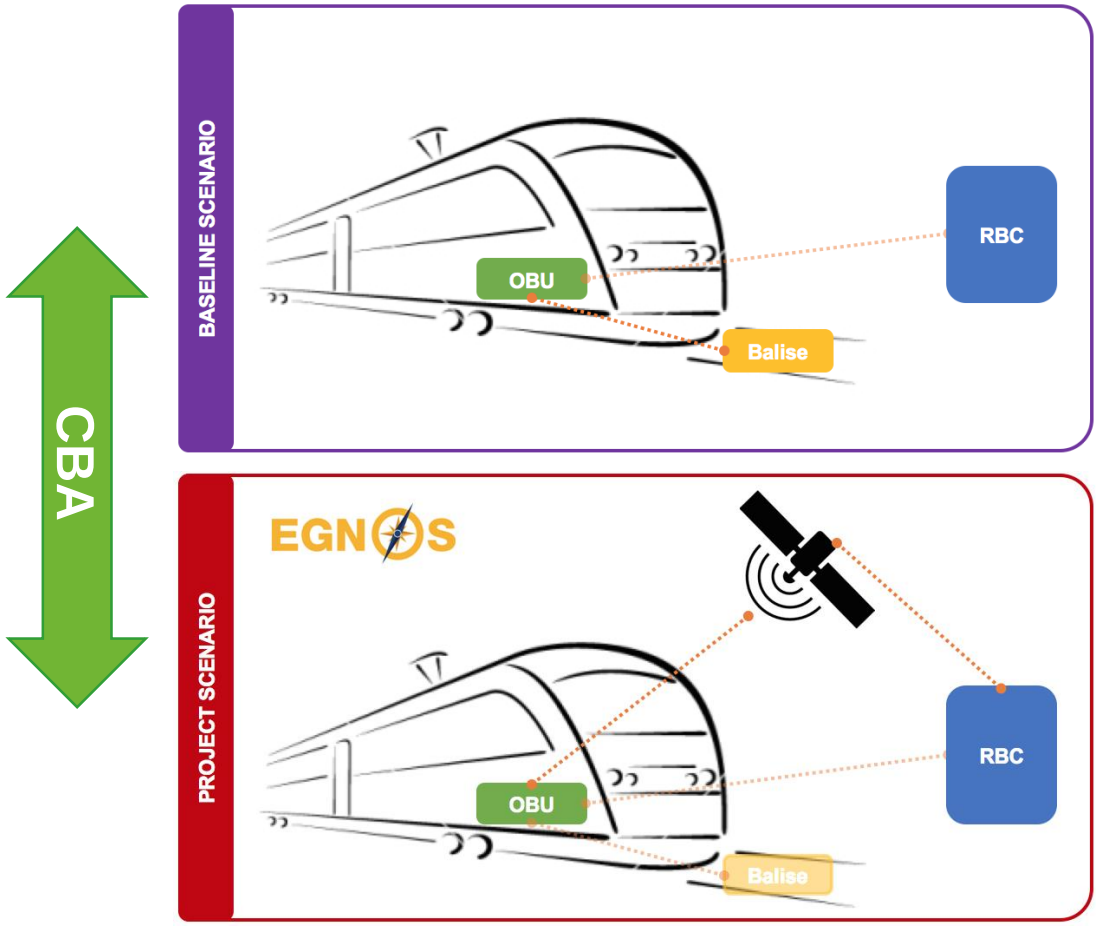
- A model to analyse cost – benefit for individual applications has been developed, which can be applied for individual analysis with customer and application specific cost and benefit figures.
- The performed analysis shows that a positive Benefit/Cost ratio can be achieved in local and regional lines, but is challenging in mainline applications.
- The sensitivity analysis has shown that the cost of the additional on-board module and the saved balises dominate over the cost of maintaining balises, meaning CAPEX dominate over OPEX.



Achievements and Results of the STARS Project, WP6

Some issue have however been identified which require further investigation

- The scenarios for local, regional and main lines need to be refined in order to closer represent the Trans European Network, where open access to all railway lines is crucial.
- Depending on the final architecture a number of additional cost items might need to be included (additional sensors, map matching, on-board route map).
- Costs and benefits will have to be balanced between stakeholders, as the benefits of using GNSS lie mostly trackside, whereas most of the cost is generated on-board.



Summary of the Overall Results

The STARS project has shown that there is potential in applying GNSS for safety critical applications in the railway environment.

- Due to significant impact of local effects on performance resulting from the challenging environment a solution with sensor fusion, and possibly map matching will however be required.
- Especially critical will be the generation of initial position fixes at start-up, as local effects are more significant in stations and the impact is more significant at standstill.
- EGNOS will have to distributed to trains via radio, as the reception from geostationary satellite is severely limited by the environment, with large areas of complete unavailability.

Summary of the Overall Results

- It has been shown that the concept of a MOPS similar to the one in aviation is not suitable for the railway environment, as:
  - GNSS is not a continuously working system in the railway environment, but only works intermittently.
  - Also current algorithms for the calculation of the protection level generated wrong results.
  - Local effects cannot be embraced by a simple MOPS, unless worst case values are used across entire lines, which degrades the achievable performance dramatically.
- The cost – benefit aspect needs to be analysed further, using detailed figures from customers (which signalling suppliers can not share). The questions of network access, as well as interoperability will have to be analysed further.

Next Steps

A number of issues have been identified which require further investigation:

- New, standardised PVT and PL algorithms will have to be developed which can better cope with the environment, but still provide high performance
- The feasibility of cost effective on-board functions for the detection and mitigation of environmental influences needs further analysis
- The use of additional sensors to complement GNSS, including the development of algorithms for sensor fusion (addressed in Shift2Rail) will have to be analysed.
- The use of signalling information and map matching functions to support track selectivity of GNSS based positioning will also have to be investigated.

Next Steps

- A service provision of EGNOS to railway applications will need to be developed and implemented
- A standardised format for GNSS referenced track data will need to be developed, to provide track geometry data to the ERTMS system. Note: Depending on the final architecture, this will either be in the form of a track database stored on-board the train, or in track to train messages containing track data for each movement authority.
- If an on-board stored track database will be used, standardised processes and interfaces will have to be developed to produce, distribute and upgrade the track databases.

Special Thanks

I would like to stress that the execution of the project would not have been possible without support from the three host railways, which in different ways contributed to the three test sites:

Czech Railways

RFI / FS

Swiss Federal Railways SBB

STARS
SATELLITE TECHNOLOGY
FOR ADVANCED
RAILWAY SIGNALLING

Thank you for your attention!

Bernhard Stamm
SIEMENS Mobility
Hammerweg 1
8304 Wallisellen, Switzerland
+41 79 217 7667
bernhard.stamm@siemens.com

http://www.stars-rail.eu

European
Global Navigation
Satellite Systems
Agency

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 687414