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Rail freight automation in Shift2Rail – Development of prototypes

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Abstract

The Shift2Rail pillar "Technologies for attractive and sustainable European Freight" (IP5) has a clear target vision, which can be summarized in two words: Digitization & Automation. The IP5 members want to speed up the digital transformation and automation of rail freight to ultimately gain market share in the competitive race with other modes of transport. In order to advance automation, multiple projects have been launched under funding. Two key technology demonstrators are presented in this paper:

1. Semi-Automated Operation with Distributed Power Systems (DPS) for efficient Master-Slave Operation, e.g. push-pull operation or in long and heavy trains up to 1,500 m
2. Automatic Train Operation (ATO) with Obstacle Detection (OD) on network sections with European Train Control System (ETCS) from Level 2 upwards

Keywords: Robotics / Platooning / Automation in Goods Transport; Onboard Technologies; Energy Efficiency; ICT Technology Applications; Transition to Automation; Driver Advisory Systems, Longer Trains, Distributed Power System, Automatic Train Operation

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Nomenclature

ARCC Automated Rail Cargo Consortium
ATO Automatic Train Operation
ATP Automatic Train Protection
C-DAS Connected Driver Advisory Systems
DAS Driver Advisory Systems
DPS Distributed Power Systems
ETCS European Train Control System
FFL4E Future Freight Locomotive for Europe consortium
GBT Gotthard Base Tunnel
GoA Grade of Automation 1-4 [International Association of Public Transport]
GoA2 Semi-automated driving: ATP and ATO with driver
GoA4 Unattended Train Operation with ATP, ATO and support systems e.g. OD
IM Infrastructure Manager
IP Shift2Rail Innovation Program
IP2 IP "Advanced Traffic Management and Control Systems"
IP5 IP "Technologies for Sustainable & Attractive European Rail Freight"
MVB Multifunction Vehicle Bus
OD Obstacle Detection system
ODAS Obstacle Detection Assistant System
RU Railway Undertaking
TMS Traffic Management System

1. Introduction: The Vision for automated rail freight transport

Shift2Rail IP5 started its mission for rail freight automation with the vision to improve rail freight attractiveness, cost structures, efficiency and sustainability based on smart and green rail freight assets and technologies. The top level goals are described in a clear vision for Future Rail Freight, agreed between the IP5 partners in the beginning of the program, see Fig. 1 below. IP5 consists of 11 partners who work together under the chairmanship of DB Cargo to realize this vision, running multiple projects within various consortia. Three consortia have started their work in 2016, and from 2017, one consortium starts every year.

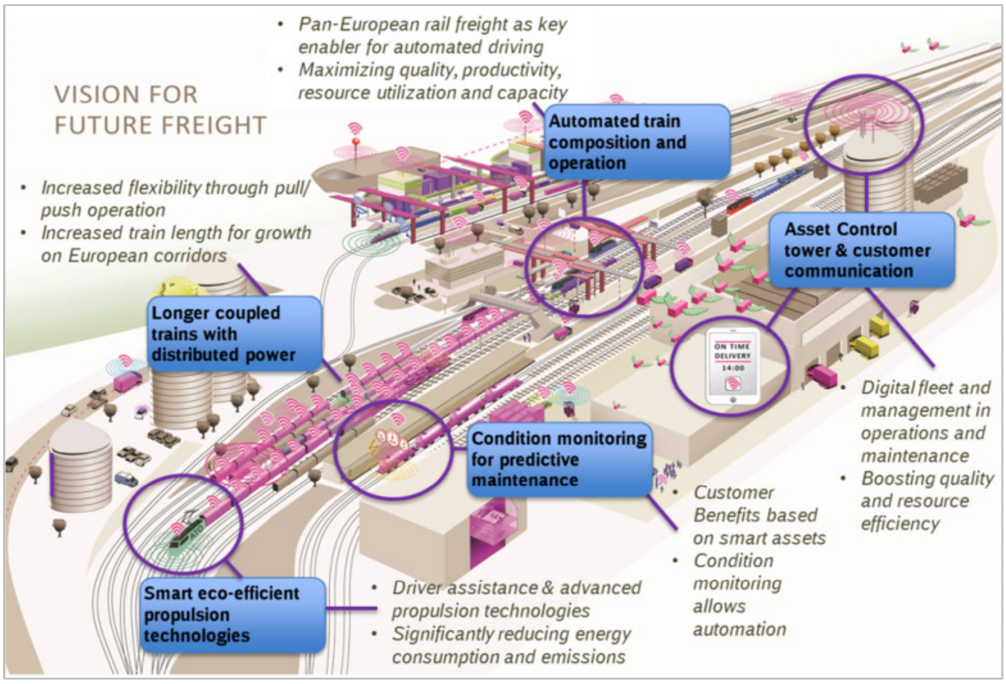

Fig. 1 Shift2Rail IP5 Vision for Future Freight

Whereas some projects in Shift2Rail evolve around committees developing European industry standards, the focus of IP 5 is on minimum viable products, with a shared mantra: Innovation in rail freight needs thee push by rapid prototyping and early demonstration to raise increased awareness of the ground-breaking impact of new digital technologies and to increase interest in a market, where framework conditions are extremely unfriendly towards innovation. This agile mindset to accelerate progress and tangibility in the development process plays an important role in the realization of the IP5 vision, particularly with regards to automation.

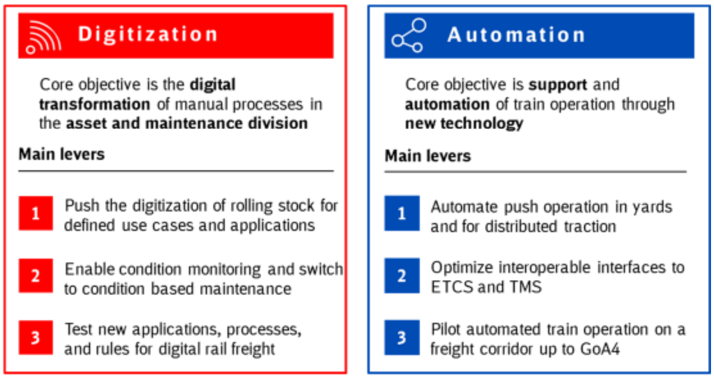

Fig. 2 Digitization and Automation in Shift2Rail IP5

The IP5 vision has guided the partners to work on numerous solutions to compensate the technological lag of rail freight in terms of asset digitization. With a focus on use cases, strategies for asset and maintenance digitization have been developed so to carry out work more efficiently, see Fig. 2. Digitization is further meant to enable automation, both in support processes and the operation of freight trains. Freight plays a crucial role regarding initial ATO testing, including interfaces to ETCS and TMS.

The IP5 partners are convinced that the future of rail freight will be highly automated transport where digital fleet steering and automated train operation will be fully integrated. To reach this vision a systemic approach is required, covering locomotives, wagons and infrastructure. This vision is larger than just the railway undertaking and locomotive manufacturer as authors of the paper. Therefore the IP5 partners also include sub-system suppliers, infrastructure managers, research institutions and more.

Three Shift2Rail demonstrators over the next three years, the first two of which we will highlight in the following, make important steps towards the vision for fully automated rail freight transport, see Fig. 3:

1. The project “Long Trains” with Distributed Power System (DPS) which is part of the consortium “Future Freight Locomotive for Europe” (FFL4E),
2. The project “Freight ATO” which is part of the “Automated Rail Cargo Consortium” (ARCC) and
3. The upcoming project C-DAS stating in the annual work plan 2018.

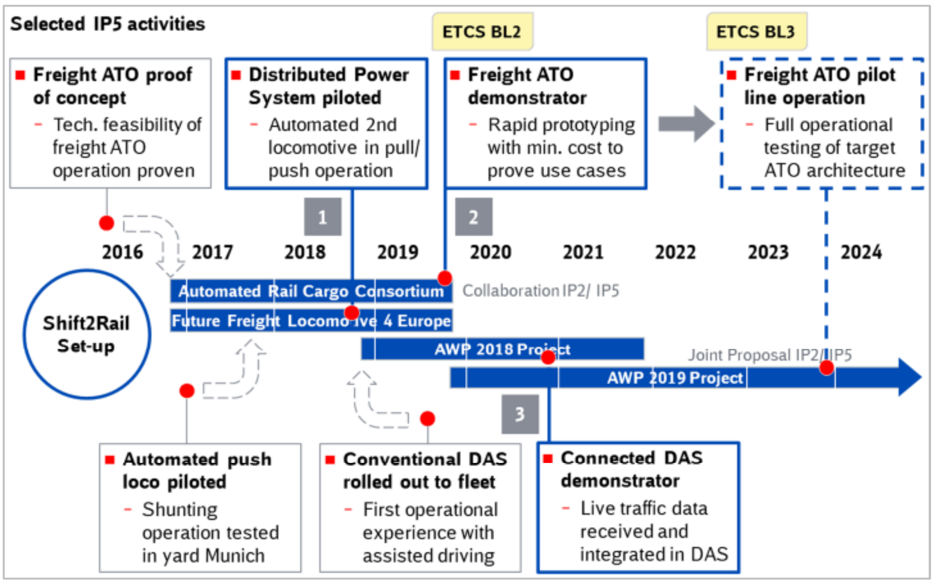

Fig. 3 Timeline with early influences and IP5 activities 1-3 for mainline automation

Early influences for these automation activities have been the technical proof of concept freight ATO on a test ring in 2016, the recent piloting of fully automated shunting in the marshalling yard Munich and valuable lessons learnt from the first wave of retrofitting driver advisory systems to mainline freight locomotives.

2. Longer Trains with Distributed Power

2.1. Project set-up and objectives

Increasing train length and weight with existing resources (locos, driver, path) is one of the most effective ways to improve productivity and competitiveness of rail freight traffic. Beside the railway undertakings it helps infrastructure managers to maximize the track utilization and to clear up room for additional traffic. Until today, there is no technology available in Europe, with UIC brake, to run multiple traction units at different positions within a freight train. A Distributed Power System (DPS) would enable operators to increase train lengths and weights beyond today's limits, from 740m lengths up to 1,500 m, thus doubling the train capacity. The objective of the S2R-project "Long Trains" is to develop and test a DPS for commercial applications. The project follows a strict user oriented and step-by-step approach demonstrating DPS in pushing locos and the refine the technology for train lengths up to 1,500 m. See Figure 4 for a graphical representation:

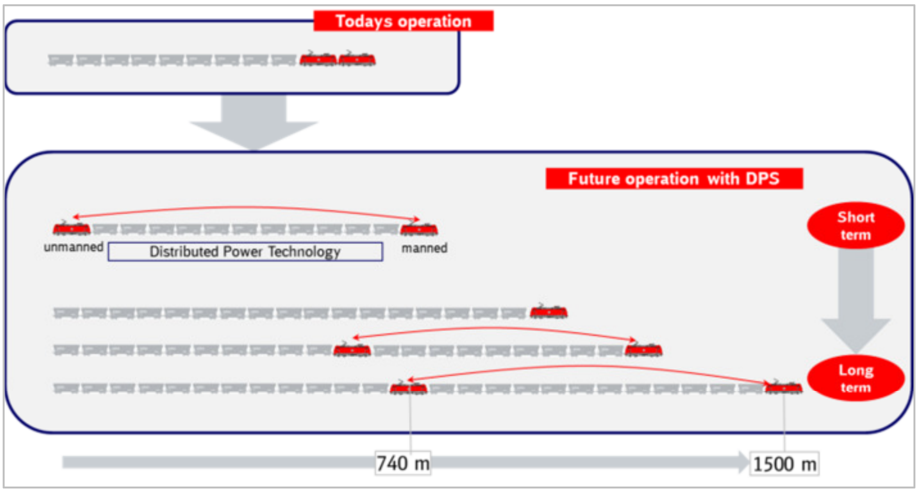

Fig. 4 Short and long term objectives of operation with DPS

Why is it a relevant use case to start with pushing action? Isn't this only a special case for ramps at which nearly every freight train has to be pushed over a steep uphill section? The topic is much more general as at first glance: Nearly every track section has a certain gradient which defines it´s so called "coupling hook load limit". Depending on the gradient it lies on many track sections between 2000 and 3000 tons. Many trains do not reach their train length limit but the limiting coupling hook load. This leads to under dimensioned trains with e.g. 500 m length and 2,300 tons weight. DPS helps to maximize the train weight and length because it weakens/removes the restriction of coupling hook load limits. By investing the same resources (two locos, one driver) trains can become longer and heavier, as shown in Figure 5:

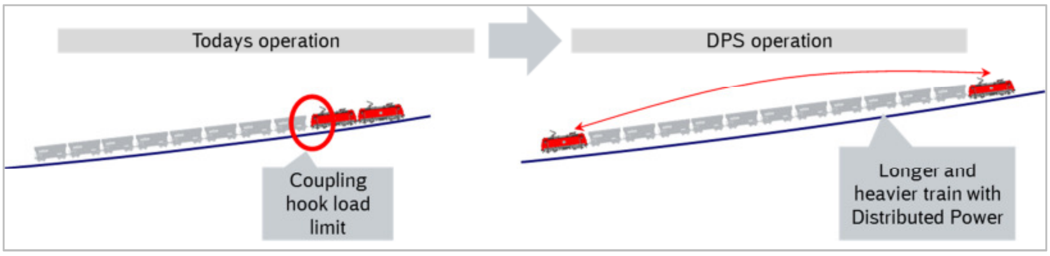

Fig. 5 Change to future operation with DPS

Using DPS for pushing action lowers production costs on a majority of routes and can be realized without time-consuming adaption of infrastructure. It helps to gain experience with radio-controlled Distributed Power to prepare the usage of DPS in longer trains up to 1,500 m. The two consortia FFL4E and DYNAFREIGHT work together to analyze the longitudinal in-train-forces and to develop the DPS-technology. FFL4E with DB Cargo / DB Netz, Bombardier Transportation and Faiveley Transport (Wabtec) concentrates on requirement specification and technology development, DYNAFREIGHT with Laird Controls Europe, Stadler Rail, KTH Stockholm, Politecnico di Milano, TU Berlin focusses on radio communication, simulation and safety management. DB Cargo and DB Netz lead the project.

2.2. Research & innovation in the project

The project is organized in 5 tasks, following the major topics for long trains:

Requirements and use cases
Starting from the as-is-analysis of pushing action, requirements for DPS with unmanned guided locos are derived. A key success factor is to involve at an early state operational personnel like drivers to identify relevant use cases and functions for DPS. For operation of 1,500 m trains new operational rules are developed and tested.

Safety Management
Safety Management is one of the most crucial topics. Former projects like GZ 1000 (1200 m test train between Rotterdam and Oberhausen) and MARATHON (1500 m test trains in France with DPS) have shown the availability of technological solutions for test runs but it is challenging to bring DPS into commercial operation for daily business. All relevant operational scenarios have to be analyzed and hazards have to be identified and remedies to be defined in order to proof the same level of safety to run unmanned guides locos in a freight train.

Train dynamics
In-train-forces play a major role in freight trains. Operational rules for brake regimes depending on train weight and length are one important tool to control the arising in-train-forces. Bringing into the train consist additional guided locos with their own traction and brake forces changes today´s operations fundamentally. Especially in cases of communication loss all locos have to behave in such a way that bearable in-train-forces are not exceeded. Simulation of upcoming and bearable forces of a concrete infrastructure and in different train configurations are simulated and give major input to technology development.

Infrastructure and business case
Long trains have to be thought always in connection with the used infrastructure. Even todays train lengths are restricted by the availability of track length in departure and arrival yards or passing sides on the mainline. Infrastructure for longer trains up to 1,500 m needs significant adaptions in the yards and on the mainline. Especially for coupling and sharing two standard trains to one 1,500 m train needs innovative yard solutions. Simulations and prognosis of traffic development is needed to identify relevant corridors for 1,500 m trains and optimal locations for coupling and sharing yards. The resulting infrastructure investments have significant influence on the holistic business cases.

Development
The technology development is guided by user and safety requirements, outcomes of simulation of in-train-forces and the goal to demonstrate DPS in a real life environment at an early state. The chance of a new technological approach is to set standards for a future large-scale rollout. DPS will enable operators to use it as flexible as necessary to combine trains with different locos or even of different RU's. For a first demonstration Bombardier will integrate components from Faiveley and Laird into two TRAXX AC3 locomotives.

2.3. Current planning for demonstration

Fig. 6 Planning for DPS testing

In today´s operations there are some trains which are pushed over a longer distance. One example is coal traffic between Amsterdam and Munich. These trains are run between Amsterdam and Mainz in conventional double traction. With 3,500 t these trains are quite heavy. Leaving the Rhine delta in Mainz, the trains have to pass a long section of low mountains. The coupling hook load limit is 2300 t. Therefore between Mainz and Munich one of the locos is used as a manned pushing loco. In this constellation, the full train load of 3,500 t can be run over the mountains. A commercial train shall be used to demonstrate DPS technology. The train will be run in the demonstration by two DPS-equipped TRAXX AC 3 locomotives, the last of these being radio remote controlled from the guiding locomotive.

Experience from the demonstration will serve further development and the usage in longer trains up to 1,500 m.

3. First Freight ATO mainline demonstration

3.1. Project set-up and objectives

The two main partners behind the Freight ATO project in the Automated Rail Cargo Consortium (ARCC) are the co-authors of the paper, DB Cargo and Bombardier Transportation. Both together strive to demonstrate the technology readiness of ATO technology for application in rail freight in the next 5-10 years, based on the currently operational core fleet of DB Cargo. Together with the consortium members Trafikverket, Slovenian Railways, Ansaldo STS who have dedicated budget for complementary works from railway undertakings' points of view, and with the key technology partners, who oversee the development of ATO modules for various application areas under H2020 funding, ARCC will test, for the first time in Europe, Automatic Freight Train Operation on real track.

In a pragmatic approach to collaboration the named ARCC partners have teamed up with the ATO suppliers and technology partners Siemens, Alstom and AZD that are active in the Innovation Program 2 "Advanced Traffic Management and Control Systems" to achieve a first mainline demonstrator, where multiple suppliers can connect their in-house ATO on-board-units to a subset 130-adapter on the locomotive, to test the interoperability and performance in a formerly untested ETCS baseline 2 set-up. For the ETCS equipped track section required for testing, which should ideally be located on the European freight corridor A from Rotterdam to Genoa, the ARCC is currently assessing options for testing with SBB Infra, who are at the forefront of ATO / ETCS track-side development.

The objective of the demonstrator will be to showcase that with current technology, Grade of Automation 2 (GoA2) can be realized without any operational problems. The demonstrator is planned to also include obstacle detection for mainline running, which is one of the key developments to realize the higher grades of automation. Whilst performing the GoA2 demo, with the non-vital use of the obstacle detection, the partners want to make a clear statement that the aim of rail freight automation ultimately is GoA4, where automation will enable driverless operation of freight trains in an integrated approach with leaner customer-oriented processes, covering transport management from order to disposition to delivery.

The main business driver in the first step, GoA2, is energy-efficiency. According to estimates, specific energy consumption can be lowered up to 20% compared to unassisted manual driving, and roughly 10% compared to conventional driver advisory systems (DAS). Quality gains come on top. In GoA4, the quantum leap in flexibility, punctuality and reliability is expected to stimulate immense growth of the demand for rail freight achieving eventually the aspired shift to rail. The fact that trains will drive autonomously in the long term vision should be seen as less of an effort to reduce personnel cost, but more of a measure to counter the lack of train(ed) drivers, which will worsen in light of demographic change and slowing interest in the traditional job profile.

3.2. Research & innovation in the project

Research & innovation inside ARCC focusses on and around the Freight ATO demonstrator. Having realized that the standardization committees alone which work towards interoperable standards for an ATO/ ETCS target architecture, will not convince potential investors, the project partners agree that speed is key in the testing. Therefore in various cross-IP workshops, the partners have defined fast prototyping of Freight ATO with minimum cost and maximum research results as underlying project rationale for Win-Win collaboration. GoA 2 demonstration is planned in a set-up where the TRAXX AC2 / locomotive class 185.1 CH with just minimum changes to the ETCS on-board will be equipped with an ATO on-board module from Siemens (developed in IP2, generically homologated Thameslink protocols), in a Baseline 2 approach where relevant input parameters for the ATO calculation are obtained directly over the MVB-data bus.

The project is a first in many regards:

1.) First Freight ATO test with a freight locomotive on a European freight corridor
2.) First realization of ATO in an ETCS Baseline 2 set-up, "listening" on the MVB
3.) First testing of interoperability of ATO modules, using a UNISIG Subset-130-type adaptor
4.) First measurement of energy-efficiency of the ATO / ETCS setups based on black box data
5.) First testing of obstacle detection in the network, with live sensor data fusion

As an innovative part of the ARCC project, the partners will develop, test and demonstrate an obstacle detection (OD) system for mainline applications. While the ARCC project partners are focusing on the short and mid-range distances, the long-distance detection system is developed by the Shift2Rail Open Call Consortium SMART, which has been granted funding as “Open Call”. Figure 7 visualizes the three ranges.

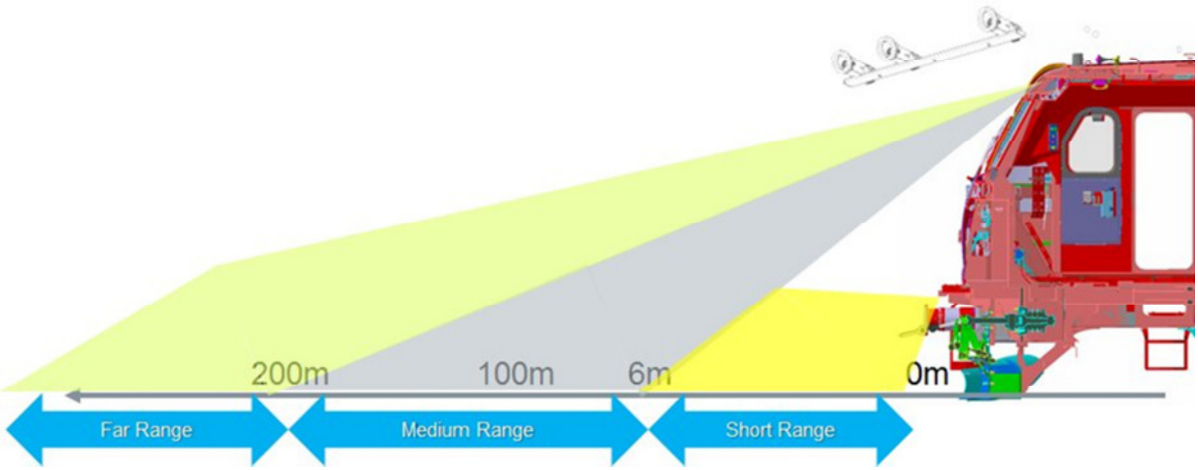

Fig. 7 Visualization of the three detection ranges – short, mid-and long distance [A. Mazzone, N. Hohenbichler]

Autonomous operation will clearly require OD although the relevant use cases are still being disputed. Questions such as: “Does such a system really need to detect an obstacle in 1000m distance? How shall such a system react if an object is detected in a distance of 500m but the braking distance is 800m?” are posed. In the approach tested in ARCC, an on-board OD system only will be responsible to avoid collision with obstacles on the track. In freight automation, not only reliable obstacle detection is required for ensuring a safe operation, but also precise object detection is necessary. Precise stopping in front of a parked freight wagon for instance, is a base requirement for the autonomous operation envisioned by the project. Due to the limited resources within the ARCC project, the first focus has been set on the detection of objects in the range of 0m to approximately 150m while running at max. 140km/h.

The system that will be tested is built on the Obstacle Detection Assistant System (ODAS), an anti-collision assistance system for light rail vehicles, developed by Bombardier Transportation together with two partners. The ODAS is a commercial product and is already in operation on light rail vehicles in various cities. Three cameras working in stereo-vision modus are continuously monitoring the area in front of the vehicle and produce an acoustic alarm if an obstacle is detected.

In the ARCC project, the ODAS [L. Fel] is further developed to fulfill the more challenging requirements of longer distances and higher velocities. Furthermore, an additional system will be integrated for precise detection of objects in the short-range distance down to 0m. Both systems, the short- and mid-range object detections system shall work in all weather conditions, including day and night and shall provide in real time the distance to the closest part of the object. Sensor fusion will be implemented in the vehicle logic that will control the traction and brake commands.

With the five points of innovation listed, it is evident, that not all questions can be answers in the very beginning but some remain to be answered. E.g. questions regarding the data exchanged on the ATO / AFB interface to be realized are still under discussion. The ATO module as core element of the auto-pilot could command traction and brake directly, or alternatively just communicate the target velocity to the AFB. Another discussion concerns the integration of the OD system in the demonstrator. Long and short range sensors should ideally be integrated, but it is yet to be clarified if Bombardier can process data from the long range device, designed and built by the SMART consortium, in the base software used for the in-house system.

3.3. Current planning for demonstration

Given that the ATO will optimize the running of a the train according to a) safety, b) acceptable punctuality and c) energy-efficiency, the current planning for demonstration focusses on the most simple, but also most relevant use cases:

- Automatic driving and braking following pressing the „ATO button“
- Safe realization of ideal speed profile in adherence to ETCS braking curve
- Taking into account (simulated) live traffic data from TMS in the calculation
- Smooth braking and accurate stopping at destination
- OD system supervises track section ahead, sensor data fusion visible on laptop

The test locomotive shall perform these core use cases in as many test runs as will be possible following the engineering required, within the first quarter of 2019. Following the agreements with the ATO suppliers, it will soon be clear how many different setups will be realized and tested. Generally, from a technical point of view, the demonstrator builds on an ETCS Baseline 2 test architecture, where besides the ATO module, ATO display and the subset 130 adapter for other suppliers, the OD system will be integrated. Further innovation, which DB Cargo is working on in-house may be added in to the demonstrator, e.g. the “TechLok” box for Condition monitoring and self-surveillance of the rolling stock.

The partners are convinced: Research needs to focus on ATO/ETCS performance under real conditions, on the learning from testing on real-track as opposed to simulation only. The tests are foreseen to take place on a locomotive from the live fleet on the Swiss GBT section of the important European Rotterdam-Genoa freight corridor. Although a commercial set-up had been identified, testing will need to be non-vital at first to work with the given budget. In the same regard, the suppliers are held responsible to avoid or else, minimize, the need for re-certification and re-homologation. Current planning foresees that one test locomotive will be fitted with the technology for testing, for a period of three months.

4. Summary & Recommendation

Shift2Rail IP5 develops multiple prototypes to pursue the vision of digital and automated rail freight. Two of them have been presented in this paper

1. Automated Push Operation has been subject of previous testing by DB Cargo in the well secluded eco-system of hump yard operations. The planning of the Shift2Rail demonstrator however focusses on mainline operation with two traction units in the train consist, where the first locomotive in front controls a second unmanned locomotive in push operation. In the current state without automatic couplers or wireless train backbone, the technology of choice for DPS is radio transmission between the traction units. The ambition is to achieve a technological solution which can serve as future standard for DPS between locomotives from different manufacturers. One of the key challenges is to bring together the partners from different consortia in order to achieve a mature solution for quick market uptake.

2. Automatic Train Operation is one of the top priorities in Shift2Rail. The migration from conventional driving to the higher Grades of Automation (GoA) has the potential to finally generate a return on ETCS investments, both for RU’s and IM’s. The ambition of the running IP5 project is capitalize on the large-scale planning in ATO development (IP2) by running a fast prototype of freight ATO including short, and long range obstacle detection. With minimum changes to ETCS, selected freight use cases shall be tested, to lay the foundation for the piloting of the target ATO set-up in a consecutive call. A key challenge is to operate on the interface between Shift2Rail consortia and to agree on priorities for in an agile approach to innovation, where speed and customer feedback are put first.

Both developments are driven by use cases and rely on prototyping and early pilot operation on real track. Both projects face the challenge of addressing the automation of the rail system which always concerns rolling stock as well as infrastructure. In the international business of European rail freight, interoperable systems and open architecture pose a common challenge.

The paper recommends that following the individual demonstrators, in the long run, both project outcomes should be combined in an integrated technology demonstrator: The automated optimization of the driving style of a long train with multiple traction units should be realized with a combination of DPS and ATO, processing information from ETCS, together with intelligent alerts from DB and traffic management. In an integrated demonstrator, DPS and ATO should be further supported by IP5 base technologies, e.g. automatic coupling and sensors for condition monitoring and automated brake testing. An integrated demonstrator is recommended to take place on a cross-border section of a European freight corridor, promoted as European testing field for ATO.

5. References

International Association of Public Transport, 2012 - A global bid for automation: UITP Observatory of Automated Metros confirms sustained growth rates for the coming years.

A. Mazzone, N. Hohenbichler - Schienenfahrzeugtagung Graz 2017 - Lokomotiven - Trends in der Entwicklung der Triebfahrzeuge.

L. Fel - WCRR 2016 - SPARK Proceedings – ODAS Obstacle Detection Assistance System.