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Positive Train Control

a cost-effective solution for the Mining & Freight Sector

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Summary

The global Mining & Freight Rail Signalling market has gone through turbulent times with the slowdown of mining since 2013. As commodity prices are recovering, now is the right time to make investments into the future of Heavy Haul infrastructure. In particular, areas of enhanced safety, increased efficiency and new digital solutions are increasingly important. A scalable approach with low entry costs and the ability to grow later is a frequent requirement, whilst low operational costs are always a key objective.

Positive Train Control (PTC) offers substantial benefits on two levels: On one hand, it is able to deliver the required safety (at levels SIL 0 to SIL 4) and on the other hand it offers a path to a number of automation improvements for enhanced operational efficiency, which will minimize the operational expenditures of the customers. Less equipment in the field allows lower cost on maintenance and reduced risk of vandalism. PTC also offers a higher degree of flexibility in creating a customized and scalable solution. Driver Assistance and Automatic Train Operation features allow greater levels of efficiency in operation and reduce fuel costs.

1 Introduction

1.1 History of Positive Train Control (PTC)

The President of the United States signed into law a "Rail Safety Improvement Act of 2008". This arose from an accident between Metrolink and UPRR trains in Chatsworth, California on September 12, 2008 – causing 135 injuries and 25 fatalities, and damage worth 7.5 mUSD [1].

The Act instructs "certain freight and passenger railroads to implement PTC on their main lines by 2015". This deadline has so far been missed and an extension granted by the FRA until end of 2018. A July 2018 FRA report indicates that possibly all railroads will seek to qualify for an extension beyond the December 31, 2018 deadline, mostly for completing testing of their PTC systems [2b]. Hence, execution is still ongoing.

The Act's targets are rail lines with intercity and commuter rail passenger transportation, poison or toxic-by-inhalation hazardous material transportation, as well as other tracks as the "Secretary may prescribe by regulation or order". It was estimated that the US would need to equip about 20,000 locomotives and 100,000 miles of track with PTC.

1.2 Why „Positive Train Control"?

Train protection systems have been in practical testing at least since the beginning of the 1930s in Europe. Stopping an unsafe running train is the main goal of any train protection system [2a]. This is most easily done with stop order, and without a special order the vehicle is allowed to run. A typical representative for this so-called „negative train control" is "Indusi" (German for "inductive train protection").

In contrast to this, a PTC restricts the train movement to an explicit allowance; movement is halted upon invalidation. PTC has been developed to take advantage of the best modern technology to provide a safe, cost-effective and fit for purpose train protection system that can be easily deployed across an existing rail network.

2 Technical Concept of PTC

The main concept of PTC (as defined for North American Class I freight railroads) is that the train receives regularly updated information about its location via GPS and where it is allowed to safely travel, also known as movement authorities, via radio. Equipment on board the train then combines this information with its own knowledge of its speed, direction and the track profile to enforce this movement authority, preventing unsafe movement. PTC systems may work in either dark territory or signalled territory, and they use GPS navigation to track train movements.

PTC is designed to reduce the number of incidents due to excessive speed, conflicting train movements, as well as the failure of the driver to obey wayside signals [2b]. The objective is avoidance of train collisions, unprotected worker zones, train movements through incorrectly locked points and train integrity failures. These targets are achieved by setting correct speed restrictions and stop locations to trains according to track profile and current signalling status.

In the technical sense, PTC can work together with signals but this is not mandatory, as in case the locomotive is violating a speed restriction or movement authority which has been sent via radio, onboard equipment will automatically slow or stop the train.

In the US, The Federal Railroad Administration (FRA) has listed among its goals, „To deploy the Nationwide Differential Global Positioning System (NDGPS) as a nationwide, uniform, and continuous positioning system, suitable for train control." [2a]

For the rest of countries PTC can adapt to worldwide location needs by integration of most popular Global Navigation Satellite Systems (GNSS), not only GPS. It can even work in multi-constellations to improve precision using multiple satellite networks.

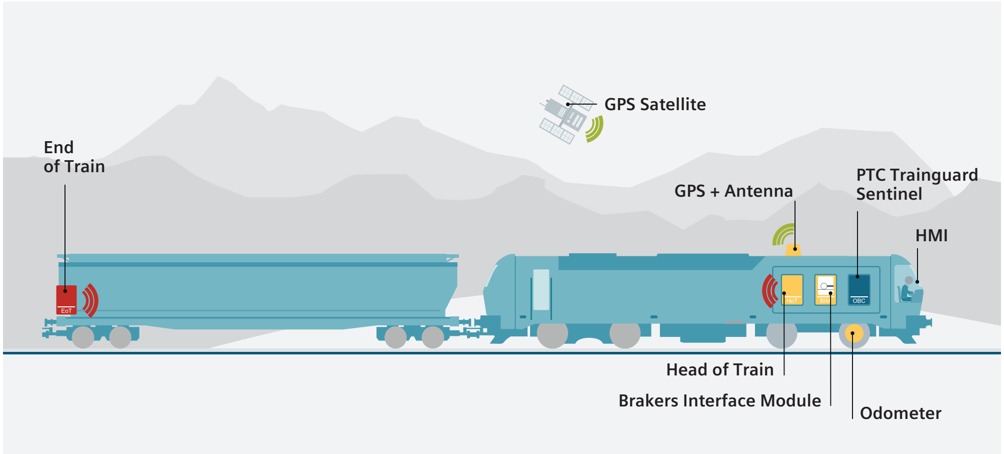


Figure A:
S tand-alone PTC solution

The Siemens gateway to PTC with such satellite-based stand-alone solution are Trainguard PTC (for the North American Market) and Trainguard Sentinel (for all other markets). They are focusing on an easy-to-enter option, while offering seamless upgradability to gain operational efficiency.

Trainguard Sentinel includes an on-board system, either as docked-in tablet solution or with a fixed installed on-board computer. It delivers speed monitoring and a time-optimized speed profile. Trainguard Sentinel includes the on-board unit GPS positioning and an odometer sensor to determine location. The system can be expanded with optional brake interfaces and train integrity monitoring using head-of-train and end-of-train devices. It also uses wireless communication for voice and data. It regulates speed, logs driver's actions, and monitors the position of the train in areas with satellite position signals. Thanks to the use of speed sensors, the position can be monitored at the end of the trip by checking the log, even for areas without satellite position coverage.

Figure B:
On-board computer

Figure C:
Human Machine Interface

In addition to all the features of the stand-alone solution, the integration of the Operation Control Center (OCC) allows movement authority, temporary speed restrictions, and transparent train position and data.

Dispatchers, working at the control center, can manage the network by setting and sending movement authorities or temporary speed restrictions to the trains via radio network. The control center also displays the railway layout to show position of each train and status of movement authorities to dispatchers. Position of trains are updated via their satellite positioning system, odometry and the trackside vacancy detectors (if available).

As soon as a movement authority is set, point machines and signals are set (if available) via object controllers and information is sent to train over the radio. When train receives any movement authority via radio, this information is computed onboard and the stop locations and speed limits are monitored by the onboard. All relevant driving information is displayed to the driver in an HMI screen and onboard keeps monitoring train integrity with end-of-train device and supervising speed, applying brakes if needed, till train reaches its assigned destination.

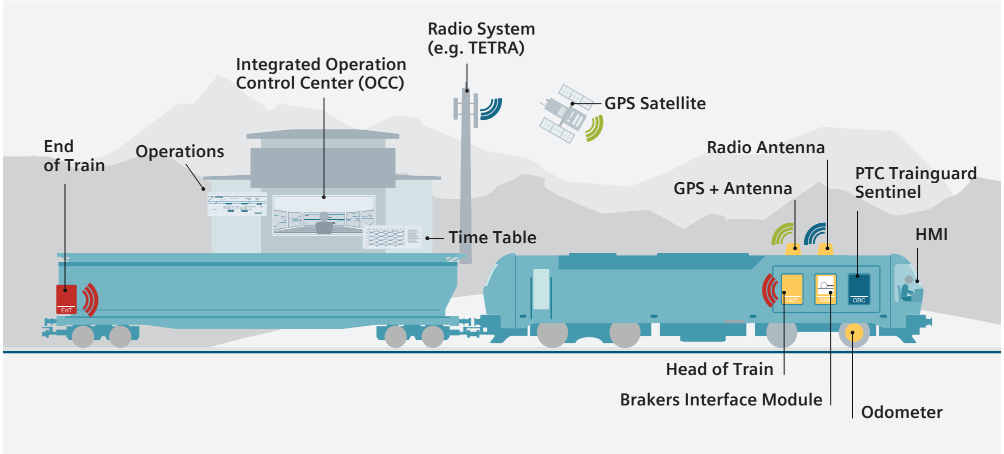


Figure D:
PTC solution – integrated into Operational Control Center

The above described integrated system also allows the update and release of locked areas in case of communications failure. It utilizes a double confirmation process that intervenes between the driver and the OCC operator. Locking of areas or definition of reduced speed areas for track work is also possible.

In regards to communication, PTC Trainguard Sentinel can work on a wide variety of transmission networks to exchange signalling data between trackside and trains, such as TETRA, UHF / VHF, LTE or even GSM. Digital radio is the most common network used in most projects, as it allows the combination of voice and data with an appropriate balance in performance and costs. For degraded situations, the system can also work with satellite radio (e.g: Iridium) as a backup, in areas where main radio network is not available or in case of failures on it. This flexibility in being able to use any available radio system allows customers to deploy the most cost-effective solution possible for electronic train control and to use its voice capabilities in the meantime.

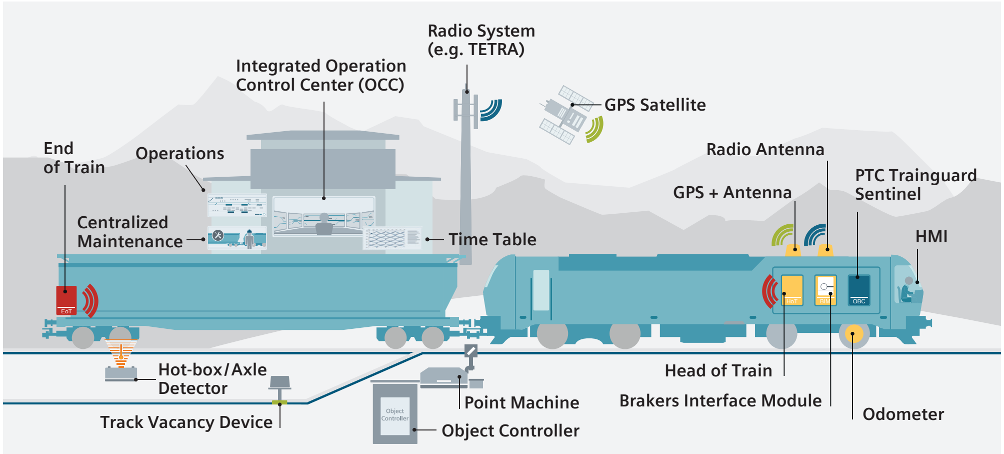


Figure E:
PTC solution – with remote point machine control and increased safety features, e.g. hot box / hot axle detection system

PTC solutions can also be adapted to existing interlockings or serve with other wayside products. The PTC Trainguard Sentinel solution, for example, can include SIL 4 electronic interlockings, point machine detection, speed monitoring, hot-box / axle detectors, derailment detectors, or track vacancy devices such as axle counters or track circuits. It may also integrate wayside signals and road crossings. Trainguard Sentinel can interface the existing wayside systems or provide new wayside solutions to enhance the safety and operation of the trains.

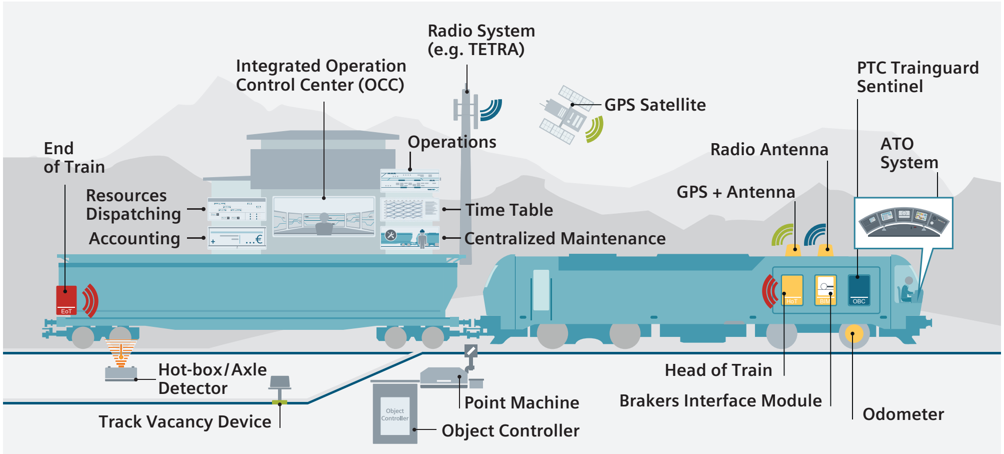


Figure F:
PTC solution – with automation features

In order to allow full automation and therefore operational efficiency levels, Siemens is then in a position to offer scalable upgrades. Trainguard Sentinel can be configured for tunnels and underground operations. The optional operations management solution allows the integration of train control into the production and logistics chain of the operator. This solution improves management of both the fleet and staff. The Operational Control Center solution Rail 9000 in combination with the Train Planning System "HaCon TPS" offers the option to monitor and enhance the logistics, fleet, finance, and operations functions of the operator.

Various other benefits can be associated with Trainguard Sentinel such as increased fuel efficiency by Driver Advisory System and / or locomotive diagnostics.

Obtaining a recognized and appropriate safety level is key in the rail industry. As an example, Siemens Trainguard Sentinel solution has implemented the following technical measures, in order to achieve CENELEC Safety Integrity Level SIL 2:

- A well-defined set of safety procedures to cope with operational scenarios that includes the hazardous situations
- Safe on-board control of the train brakes (through a dedicated module)
- Safe train integrity through an industry standard and proven head-of-train and end-of-train connection over separate hardware with a constant radio connection plus the brake pipe pressure supervision
- Safe locking and detection of point machines and
- A safe method for monitoring track vacancy / occupancy at rail intersections (normally through axle counters).

Due to nature of modular design of Trainguard Sentinel, in case the application does not require to meet SIL 2, end-of-train device and brake application module can be removed from the system, excluding train integrity feature and safe brake application from its configuration. In this case, the brakes can be still commanded by the main computer.

3 Current PTC Projects

In this entry level form, PTC is a mature technology with numerous installations in successful operation. Subsequent developments have customized the concept to particular customer needs. There are three examples of particular relevance to the needs of Heavy Haul [4]:

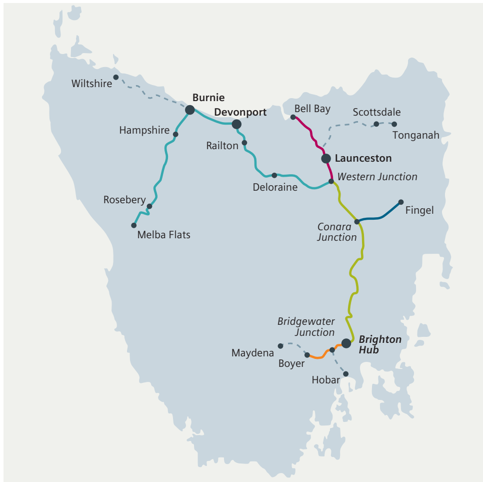
- Panama
- Tasmania, Australia
- Nacala, Mozambique

3.1 Panama

Panama Canal Railway Company was implemented on a 76 km line with 18 EMD locomotives, VHF-based communication and solar powered, remotely operated point machines.

3.2 Tasmania

The installation on TasRail controls 632 km of tracks with 26 locomotives built by EMD, New Progress Rail and English Electric, DMR-based communication, allowing full visibility of all vehicles on the network in real time. This is a simplified installation without a direct brake interface. In those operations, the aim is to apply for and receive digitally recorded, hence paperless, movement authorities for each trip and to give out clear warnings to the driver, when he is over-speeding, according to the current train consist data, as well as the maximum gradient of the trip.



3.3 Mozambique

As a next level of development, the project installations made in Mozambique, Nacala integrate a network of 912 km main tracks, a communication based on Tetra with a satellite/ Iridium based overlay. Being certified as a SIL 2 [5] train control solution, it has reduced track side equipment (no signals, no balises), while adding safety through hot box and hot wheel detectors, as well as using a derailment prevention system. 129 locomotives from a number of different brands, such as GE and EMD and a total of 9 different types are being used. In June 2018, a contract was signed for the next project for a different operator in Mozambique for a 500 km line. The target is the Nacala SIL 2 concept with a higher grade of automation at even more reduced hardware, especially between the stations. This type of success encourages us to further invest into fuel saving and other operational efficiency driving technologies, in order to take advantage of, and potentially drive, further market trends.

4 Market Trends from the US

US rail operators may have perceived the Act on PTC as a pure additional financial burden in the beginning of their (delayed) implementation phase. Nevertheless, the fact that e.g. truck transportation in North America is currently experimenting on autonomous truck operations, with first cost saving innovations like platooning [3], the rail operators are currently heavily pushing for higher levels of automation. They drive towards Moving Block in combination of the potential of PTC in connection with the given options of digitalization. The main goal: They are seeking ways to reduce operational expenditures by minimizing train headways, constantly reducing maintenance cost through preventive data analytics as well as reducing fuel consumption, in order to stay competitive against truck transportation. It is expected that this US trend will drive further innovations at supplier side over the next years.

5 Future, Trends and other Solutions

The PTC market is a healthy and competitive market that is recognizing and driving market trends towards further automation and digitalization.

One basic trend for Siemens is to obtain fuel savings and better on-time trip performance according to installed movement planners through stand-alone on-board Driver Advice System (DAS) and – if possible – based on real-time information about other trains and temporary speed restrictions in the field, so called Connected Driver Advice System (C-DAS). Both DAS and C-DAS systems are designed to be natively integrated into PTC, so that fuel saving driving profiles are also displayed on HMI and adapted to current signalling related speed profiles, for driver to easily follow them.

Following proven Mass Transit automation levels in the area of Communication-Based Train Control (CBTC), the C-DAS technology will develop into a higher degree of automation, eventually becoming fully autonomous from drivers. The so-called Grades of Automation (GoA) [6] are:

- GoA 2 is semi-automatic train operation (STO) where starting and stopping is automated, but a driver operates the doors, drives the train if needed and handles emergencies.
- GoA 3 is driverless train operation (DTO) where starting and stopping are automated but a train attendant operates the doors and drives the train in case of emergencies.
- GoA 4 is unattended train operation (UTO) where starting and stopping, operation of doors and handling of emergencies are fully automated without any on-train staff.

Advanced operators, as well as suppliers, currently aim on achieving GoA 2 for general operations and GoA 3 or GoA 4 for yard operations.

The restrictive factor for GoA 3 and GoA 4 operations in the rail industry is the automated detection of obstacles in front of the trains.

In underground mines, like the LKAB Iron mine in Kiruna, North Sweden, real-time CCTV camera recordings are transmitted from the on-board system and along the trackside via WiFi network and PROFINET Bus system to the operational control center above the ground [7].

A similar approach has been taken in the Pilbara Mines of Rio Tinto an ETCS Level 2 based system intended to reach a GoA 4 level [8]. CCTV cameras are installed on board, allowing constant remote monitoring of the operations through the desert. The remote operator and monitoring staff is sitting in Perth, which is up to 1,500 km far from the operations.

While this project has consumed 940 million AUD (about 585 mEUR) and over 6 years of execution time, most other mining and freight operators will seek for substantially lower time and cost parameters for their rail infrastructure [8]. PTC technology offers a cheaper and faster route to such solutions.

6 Cost-Effective PTC Solutions

The PTC solutions being offered by Siemens are Trainguard PTC (for the North American Market) and Trainguard Sentinel (for all other markets). They are focusing on an easy-to-enter option, while offering seamless upgradability to gain operational efficiency.

Trainguard Sentinel offers as baseline a CENELEC SIL 2 certified solution, including SIL 4 Westrace Mk II interlocking object controllers and the SIL 2 certified Central Train Control (CTC) system, Rail 9000.

However, Trainguard Sentinel goes beyond just the safety critical aspects of PTC and combines with its RailEcoDrive® solution additional automation and digitalization features, in order to gain substantial operational efficiency improvements for the operators. Siemens is therefore giving customers the ability to customize and scale according to their needs. This is an exceptionally innovative and collaborative approach with customers.

Trainguard Sentinel offers RailEcoDrive® with several efficiency gaining features, such as Driver Advisory Systems with and without a connection to the operational control system.

Based on 15+ years of experience in CBTC mass transit technology, the system is also able to upgrade to Automatic and Driverless Train Operations (ATO / DTO). Transporting raw materials and finished goods efficiently, Trainguard Sentinel is ideally suited for managing safety whilst focusing on fuel efficiencies and cost savings through increased operational accuracy. This maximises return on investment.

A good example of innovative solution in the digital area is the recent Siemens acquisition of the Germany-based company HaCon with its Train Planning System [9].

The Train Planning System automatically defines and sets ideal routes and resolves conflicts in real time. The TPS connects with the Rail 9000 CTC and therefore allows trains to run automatically in GoA 2 to 4 mode – in most cases without the need of braking the train during the defined trip. Especially in the heavy haul area, this helps reducing operational expenditures, such as fuel, wheels' and brakes' wear and tear – and it helps increasing on-time operational performance.

Another good example for a simple and effective application is to equip maintainers with a tablet to help them accessing information of the operational control center. This enables workers along trackside to have a transparent view into existing TSRs (temporary speed restrictions) or simply set TSRs on their own. Supervisors of smaller mining rail operations prefer the flexibility to manage operations from outside of their office. Hence, the Trainguard Sentinel tablet solution is also suitable for full CTC functionality from outside the operational control center.

Every customer and its rail infrastructure business case is unique. Depending on the baseline, one can expect improved safety as well as avoiding expensive and disruptive derailments and collisions.

Safety is only the very basic offering PTC has. With savings on fuel, increased operational accuracy, as well as improved human efficiency, experiences and estimations of a number of operators report OPEX savings in the area of 2–20% in fuel [10], as well as additional savings through on-time operations and less equipment wear.

Higher throughput of freight goods will additionally result in higher revenues. Examples show that smoother train succession and avoidance of stopping trains during operations can bring substantial gain in daily capacity.

In summary – the key benefits of Siemens PTC solutions are:

- Speed monitoring to prevent derailments
- Optional brake interface
- Optional train integrity monitoring
- Estimation of fuel consumption
- Predefined optimal speed profiles to optimize energy consumption (RailEcoDrive® with Driver Advisory System)
- Increase of safety thanks to the use of track warrants (movements, authorities and management)
- Possibility of establishing / removing temporary speed restrictions
- Train position and train data shown in OCC
- Safety level increased through interlocking functions, e.g. point machine position detection or hot-box / axle detection system
- Derailment detection system
- Advanced energy saving management through OCC-connected Driver Advisory System (RailEcoDrive® with C-DAS) up to Automatic Train Operation (RailEcoDrive® with ATO)
- Automatic route setting and management of fleet and crew with the HaCon Train Planning System
- Customized integration into operation, production, and logistic chains

7 Conclusions & Recommendations

All global Mining & Freight Rail Operators and their Consultants are warmly invited to consider PTC as a cost-effective solution for the sector. PTC goes beyond just providing a safe, cost-effective and scalable train control solution. With features such as driver advice and autonomous train operation, it will help gaining substantial improvements for operators. It offers a number of digital innovations and therefore helps to increase operational efficiency.

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