PSI Technics

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# AUTOMATED TRAIN INSPECTION

## INSPECT. ANALYZE. OPTIMIZE.
## PSI Technics Offers an Advanced Train Maintenance Solution.

From automated visual inspection and data analysis to maintenance process optimization using artificial intelligence.

We keep AI on your train.

We keep an eye on your train.

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## Are You Ready to Reap the Benefits of Automated Train Inspection? Then this is Your Roadmap to the Future:

| PHASE 1 | PHASE 2 | PHASE 3 | PHASE 4 | PHASE 5 | PHASE 6 |
|---|---|---|---|---|---|
| CONSULTING | COMPUTER VISION | ROBOTICS | AI | INTERFACES | CLOUD COMPUTING |
| Technology consulting (Requirement engineering)<br><br>incl. a QuickStart* sensor portal prototype | Stationary sensor portal | Mobile sensors (robots, drones) | Artificial Intelligence | Human-Machine Interface (HMI) | Infrastructure Digital Twin |



*A simplified sensor portal that starts collecting digital train data at the onset of each project to ensure that relevant data is taken into account throughout the course of the project, e. g., for creating artificial intelligence models.

International rail companies are currently shouldering an enormous burden, since the transition to a more sustainable means of transportation can only be achieved by increasing existing rail traffic, which in turn requires rail operators to strengthen their infrastructure and make many of their workflows more efficient – including the inspection of passenger and freight trains.

We are leveraging years of experience in the rail and rail maintenance industries and combine them with state-of-the-art technology, including vision technology, artificial intelligence, and cloud-based analytics to provide solutions that are currently not available on the market. Thanks to our extensive train maintenance expertise, we are familiar with the needs of rail operators and focus on offering them added value by:

- Reducing train maintenance times by 50% by freeing highly qualified personnel from monotonous maintenance tasks
- Providing computer algorithms for creating consistent evaluation criteria to standardize fault detection
- Using mobile robots for the automated visual inspection of difficult-to-reach train components, such as wheel trucks
- Supplying electronic maintenance files for every train to improve maintenance documentation and increase legal certainty

Our intelligent solution for automated train inspection uses artificial intelligence and robotics to make train inspections faster and more efficient

In an industry that is affected by a shortage of skilled labor, we support workflows by means of digital processes. In doing so, we help our customers to become more sustainable and self-supporting, while increasing workplace attractiveness and reducing inspection-related workloads


Our solutions flexibly adapt to all requirements, irrespective of existing levels of digitalization. From an initial consultation to simulations to regular operation: We offer a step-by-step project implementation and tailor every project to your specific needs. You receive everything you need from a single source to make your train inspection workflows safer, more efficient, and more profitable than ever.

Karl-Heinz Förderer
President and CEO, PSI Technics GmbH

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# Automated Train Inspection Significantly Reduces Maintenance Costs for Rolling Stock

**Trains are the future of sustainable mobility.**

Trains, city railways, subways and streetcars that are used for urban, regional, passenger, cargo or long-distance transport are at the heart of climate-friendly mobility. The transition to more sustainable means of transportation poses greater challenges for rail operators, as performance, safety and timeliness requirements become increasingly demanding. Companies that embrace digital concepts, however, are able to achieve sustainable improvements.

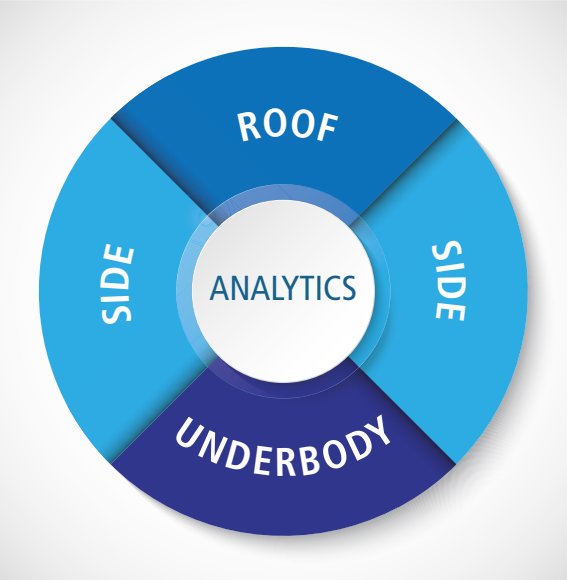
**Against this backdrop, we would like to present a new and innovative solution for condition-based train maintenance.**

PSI Technics specializes in automation and control solutions and industrial image processing systems.

To create an automated train inspection system, we developed sensor portals that are equipped with image processing systems which record and document anomalies, wear or damage to the train's **roof, side and underbody structures**.

A variety of imaging techniques enable the detailed inspection of components and reveal issues and defects that are invisible to the human eye. All findings are thoroughly documented, all in a matter of minutes. Artificial intelligence is what makes regular automated condition-based train maintenance possible, offers increased safety and ensures sustainable maintenance processes.

## THE AUTOMATED TRAIN INSPECTION COVERS




### > Advantages of automated train inspection:

- >> Significantly reduced maintenance times (the track in the maintenance shop is freed up for other tasks)
- >> Considerably reduced inspection times
- >> Noticeably fewer errors compared to human visual inspection
- >> Detailed documentation of the train's condition for subsequent maintenance follow-ups
- >> Detailed overview of potential hazards that can go undetected by the human eye

*Our innovative automated train inspection system consists of **four modules** – three modules for the inspection of the roof, side and underbody structures and an Analytics module that analyzes the recorded data.*

*The Analytics module collects data from all train inspection modules and uses artificial intelligence (AI) to analyze the recorded data volumes. It provides detailed maintenance information and recommendations regarding the train's dynamic behavior.*

*Freight and passenger trains require regular maintenance to ensure that they live up to the strictest safety and performance requirements.*

Current preventative maintenance practices for freight and passenger trains are largely based on manual or visual inspections. Maintenance is carried out by trained personnel, either in a pit or track-side, while the train is stationary or moving slowly. Those practices, however, still rely on individual maintenance assessments. In addition, stationary inspections do not account for the vehicle's dynamic behavior.

**Three levels of inspection are available:**

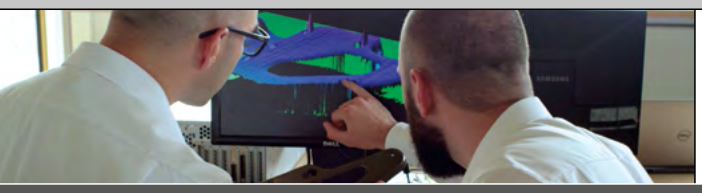
| A | B | C |
|---|---|---|
| Fully automated inspection with component-related maintenance assessment and enhanced data analysis provided by the Analytics module. | Fully automated inspection with component-related maintenance assessment. | Stationary train inspection. The resulting data is evaluated and analyzed by the user. |

Automated train inspection uses image processing technology and has the potential to overcome the limitations of traditional inspection methods.

Automated train inspection ensures that the train is on schedule and will not be delayed if otherwise it does not leave the maintenance shop on time or has to wait its turn.

## EXAMPLE ROOF-INSPECTION:

| **WITHOUT** Automated Train Inspection | **WITH** Automated Train Inspection |
|---|---|
| Additional safety measures, for example, the grounding of the rail cars and the tracks are required before the visual inspection can take place. | Images of the train are automatically recorded while the train passes the inspection system. |
| The inspector personally examines and inspects the train for damage or wear. | The train structure is analyzed automatically. The inspector displays and checks the analysis results using a web interface. |
| For the time of the inspection the train occupies a track in the maintenance shop. | If the train is in good condition, it can remain in service and does not need to be transferred to the maintenance shop. |
| Inspection time: **1.5 hours** **The train occupies a maintenance shop track.** | Inspection time: **10 minutes** **Thanks to the automated inspection, the maintenance shop is freed up for other maintenance-related tasks** |

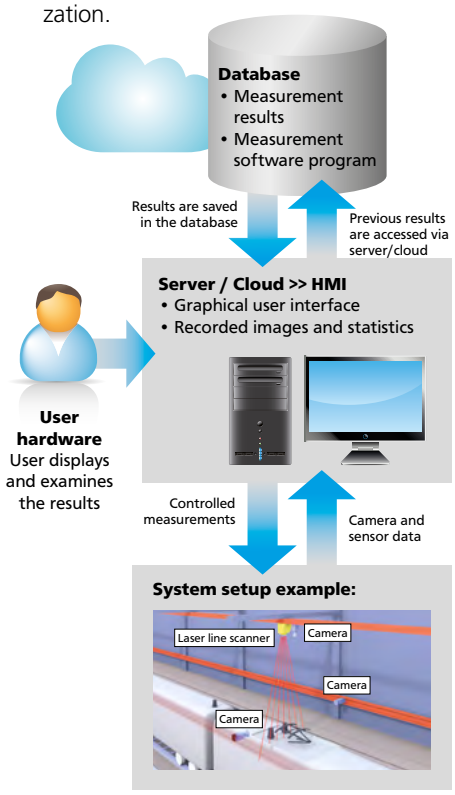


# Automated Train Inspection Modules: Inspect – Analyze – Optimize

**Automated inspection workflow for roof, side and underbody structures:**

Images of the train are recorded as the train passes the inspection system. The software uses templates to learn the characteristics of each train type, and the analysis is performed using pre-defined templates. The diagnostic software analyzes the recordings and displays the results. The rendered images are accessed via a web interface that offers the following features:

1. Display of the analysis results
2. Individual image display
3. Adding inspection notes to the analysis results (as needed)
4. Reporting / documentation of results
5. The recorded findings are used as a basis for the subsequent maintenance optimization.




## INSPECT

This module determines which inspection and measurement tasks are available. Dirt accumulations do not interfere with wear or damage detection.

**Examples for recorded potential damages or defects:**

- Wear and tear, such as indentations, spalling, cracks, breakage of single fibers or strands, traces of heavy use, abrasions, scratches, grinding marks, corrosion.
- Contact burns, surge marks
- Structural changes, deformations
- Displacement/incorrect position/misalignment, lose bolts, angular differences
- Missing or wrong components, ineffective connecting elements, protruding or loosely hanging parts, poor installation
- Heavy dirt accumulations that impair functionality
- Leakages
- Incorrectly routed cables
- Damaged insulation
- Missing pictograms or labels
- Wrong colors

  and many more

Visit
psi-technics.com/EN/inspect
to learn more.

## ANALYZE

Today, the volume of collected and digitally archived data increases exponentially. However, large amounts of valuable data are simply archived and their true potential remains unused. "Big Data" refers to data records that are too big or complex to manage with traditional data processing methods. While big data management represents a major challenge, it also harbors enormous process optimization potential.

The intelligent, self-learning Analytics software module analyzes and utilizes large volumes of recorded data to accelerate and streamline train maintenance.

**The recorded data is used for:**

- The compilation of statistics
- The documentation of results for subsequent reporting and follow-up
- Time-delayed analyses
- Identifying potential safety risks
- Identifying creeping wear
- Cloud connectivity that permits the simultaneous use of data at different locations
- Condition-based maintenance
- Creating inspection templates for additional train models
- Process optimization (data mining)
- Artificial intelligence enables the image processing system to make smart decisions

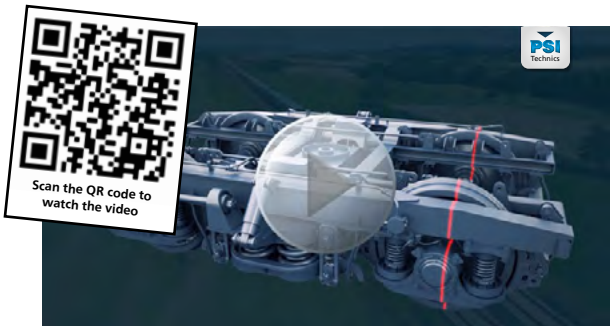
Visit
psi-technics.com/EN/analyze
to learn more.

## OPTIMIZE

**Artificial intelligence (AI)** enable systems to learn from samples. Based on large volumes of recorded and analyzed data, modern **machine learning** algorithms help to continuously improve the evaluation of quality-related properties. The obtained data can subsequently be used for further processing and analysis.

The more data is collected, the better the system "learns" to interpret potential correlations. It intelligently and automatically combines the recorded data to generate additional information for every train or component (**data mining**), saving valuable time and ensuring precise maintenance planning.

The cloud offers central data processing and storage for multiple maintenance locations. Detecting wear and tear at an early stage contributes to the optimization of maintenance processes and ensures the continuous and seamless monitoring of safety-critical components.

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# Inspection of Roof, Side and Underbody Structures: Our System Examines Every Inch of Your Train.

**The "inspection tunnel" combines 3 different modules:**
**Inspect – Analyze – Optimize**

The train is inspected for wear and tear when it passes through an existing inspection infrastructure or a dedicated "inspection tunnel"*. Since the system supplies valuable information about maintenance related issues before the train even enters the maintenance shop, it significantly reduces maintenance times and frees up the maintenance resources for other tasks. Trains that do not show any signs of wear or damage do not need to be serviced, which results in a more economical condition-based maintenance. The automated inspection system increases the availability and timeliness of trains while ensuring consistent process reliability.

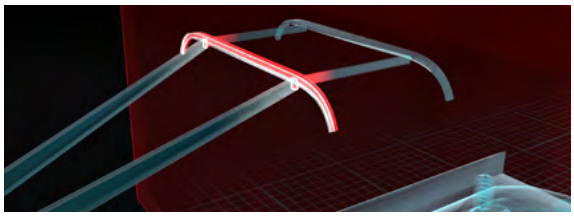
* The construction of an optional inspection tunnel does not require an architectural blueprint. The inspection tunnel can be designed according to your needs. Alternatively, the automated train inspection modules can be integrated into an existing infrastructure.

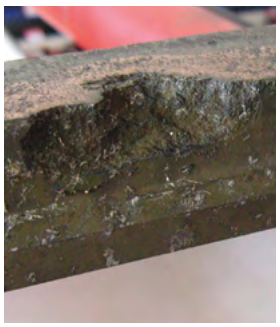
## ROOF INSPECTION

### Inspection tasks:

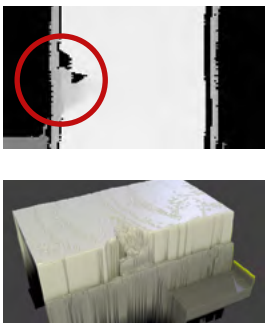
- Pantograph wearing strip and bow measurements
- Pantograph/pantograph tracking system inspection
- Canopy inspection
- Wind deflector plate inspection
- Roof surface inspection
- Insulator inspection
- Antenna inspection
- Cable and conductor line inspection
- Inspection of covers, such as climate covers
- Inspection of bolted joints/connections
- Inspection of coiled cables between rail cars
- Surge protector inspection
- Isolation switch inspection
- Inspection of high-voltage roof power lines
- Inspection of main vacuum circuit breakers
- Voltage transformer inspection
- Inspection of compressed air insulating sleeves
- Identification of foreign objects

*Inspection example: Wearing strip inspection*

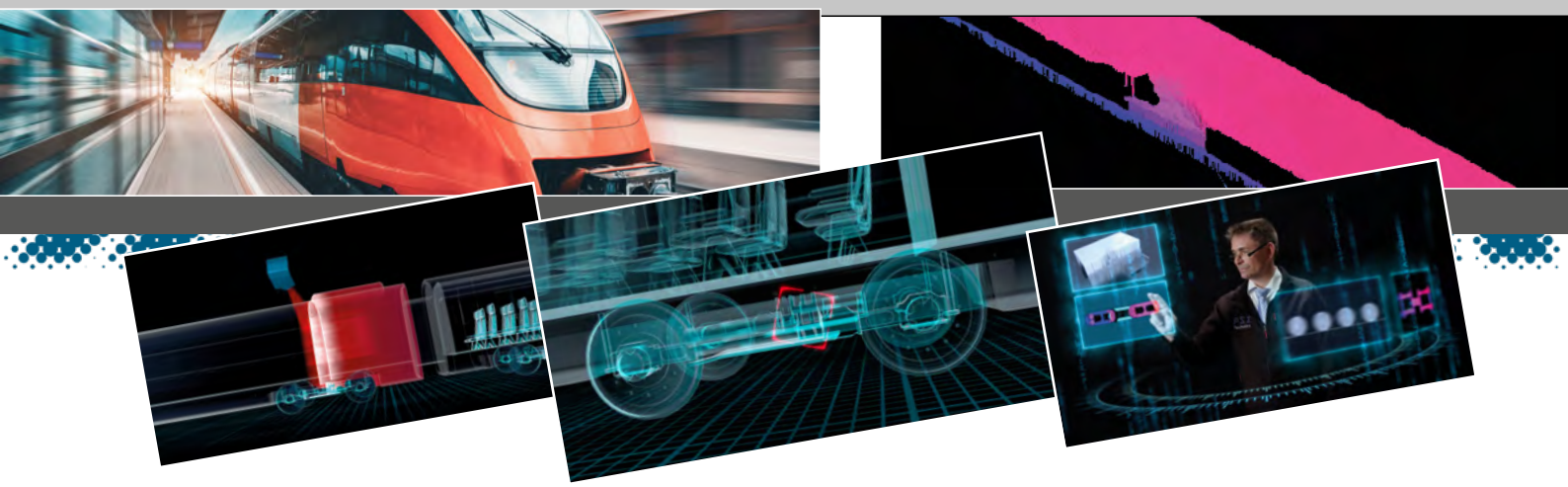




*Picture on lower left: Broken-out parts of a wearing strip section*



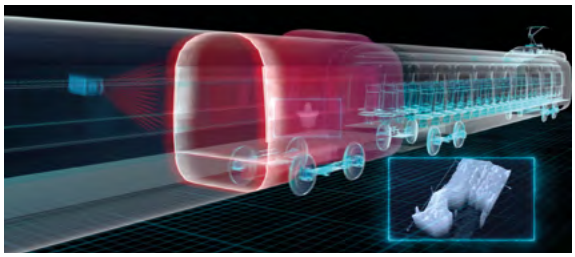
*Center right: Elevation map created by a laser line scanner*
*Lower right: 3D rendering of the recorded data*



## SIDE INSPECTION

### Inspection tasks:

- >> Running gear inspection
- >> Window and surface inspection
- >> Identification of wear or deformation
- >> Inspection of the vehicle exterior
- >> Recording of displaced or lose components that interfere with clearance
- >> Detection of open or leaking hatches, open suspended doors and damaged door systems
- >> Visual inspection of entry doors, cargo doors and folding steps
- >> Inspection of side windows and emergency exit windows
- >> Inspection of side skirts and ventilation grilles
- >> Checking for the physical presence of antennas and for potential antenna damage
- >> Detection of lifeguards damage or deformation
- >> Visual wheel truck/bogie inspection
- >> Inspection of connections/threaded/bolted joints
- >> Detection of damaged exterior paneling or coating
- >> Detection of inadequately mounted pictograms or signs
- >> Detection of graffiti on signs/labels and excessive dirt accumulations
- >> Detection of broken/missing axlebox covers and extensive wheel disk damage
- >> Detection of laterally displaced springs/shock absorbers and other wheel-related defects (non-pneumatic tires, deep or thin wheel flanges, wheel diameter deviations on the same axle, etc.)



*A combination of different sensors check the passing trains for detached or protruding parts that may have been loosened by motion or vibrations and adversely affect clearance.*

- >> Detection of worn or missing brake linings/ brake blocks, broken or missing brake beams, brake block keys, pull rods, damaged or missing hand brake wheels, broken, damaged or missing springs/suspension springs
- >> Visual inspection for deformed or curved side panels, unbalanced load, etc.

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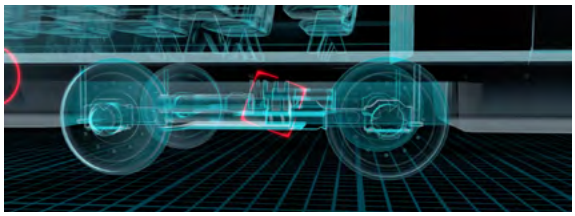
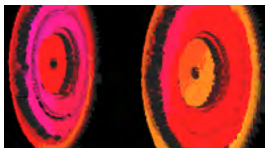
## UNDERBODY INSPECTION

### Inspection tasks:

- Wheel inspection (wheel profile, wheel set, axlebox, steel tire)
- Running gear inspection
- Base plate inspection
- Detection of visible defects that affect the underbody's structural integrity, such as cracks
- Inspection of intermediate sleepers or other components underneath the frame
- Visual inspection of earthing wire breakage/ defects
- Checking for the physical presence of antennas and for potential antenna damage
- Inspection of bolted joints/connections
- Inspection of track rods and protective plates
- Inspection of bellows
- Inspection of wheel trucks/bogies (brakes, brake block holder with brake block, primary suspension, lateral support for the superstructure, swivel ring, frame, axlebox, secondary spring, secondary damper)
- Detection of buffer overriding
- Detection of lose coupler connections
- Inspection of spring assemblies, air suspension, air lines, emergency mechanical release, spring-operated brake, rods, air suspension valves, transitions, wheel flange protection, electromagnetic shoe brake, yaw dampers, push rods, rubber elements, leakage of fluids (oils, grease, pneumatic liquid, fuel, water)
- Inspection of oil-bearing components, such as hydraulic lines, hoses, bearings, gearboxes, axleboxes
- Inspection of coolant-bearing components, such as drive equipment, heating/air conditioning
- Inspection of fuel-bearing components
- Inspection of pneumatic components, such as braking systems, pneumatic hoses





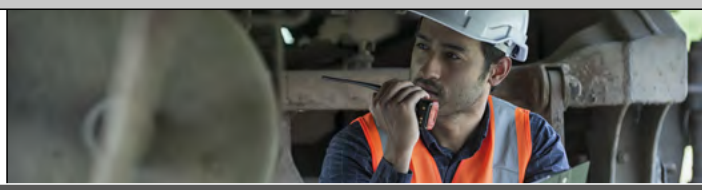
*Routine train inspections need to be performed on a regular basis. Trains need be checked for worn parts where friction heat can lead to component deformations or represent a potential fire hazard.*

- Detection of missing or broken bolts
- Detection of missing brake components
- Detection of missing CBC operating handles, damaged charging devices, broken or concealed brake beams, missing or damaged brake pipes

### COMPREHENSIVE CONSULTATIONS

We assist you every step of the way – from concept to completion. We focus on a close cooperation with our customers and extensive customer support.

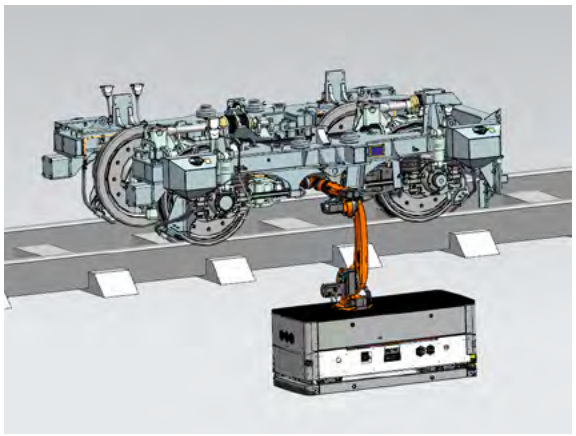
If desired, we provide expert advice and conceptual support after the implementation of the project to tailor the desired inspection modules to your individual requirements (as specified in the performance specifications) and prepare a custom estimate for you.



## MOBILE INSPECTION ROBOT

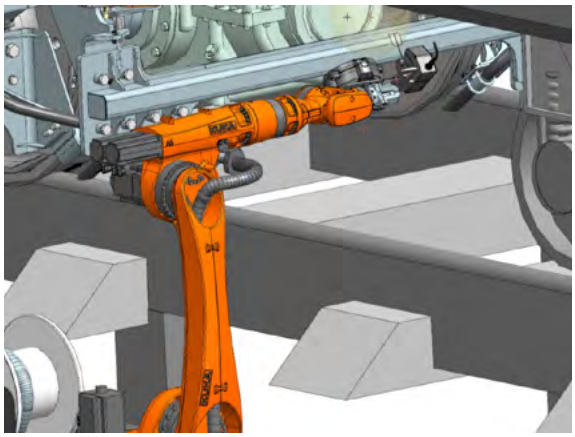
Our mobile inspection robot collects images and data in locations that cannot be covered by a stationary sensor portal.

It uses complex motion sequences to record images and data of difficult-to-access train components – the inspection of wheel truck brake linings is a good example.

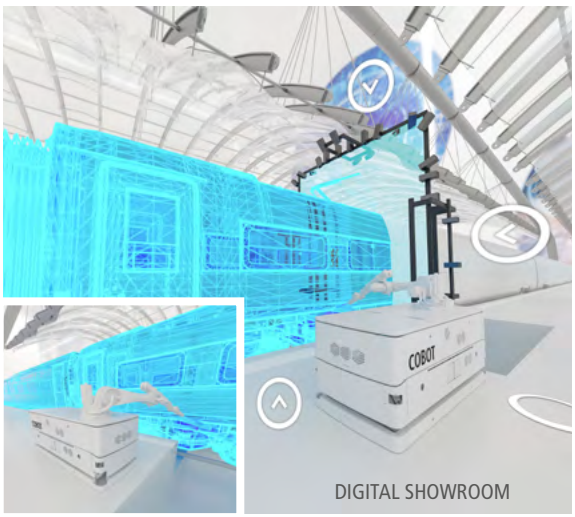


*The inspection robot independently moves along the train on an automated guided vehicle (AGV) and records the required images and data for every single car.*

Typically, the robot works alongside service personnel during train inspection. To ensure a safe human-machine cooperation, our system permanently monitors the robot's work space, placing particular emphasis on applicable standards and directives for collaborative and cooperative robotics. In addition to traditional scanners for automated guided vehicles (AGV), our solution also includes a safety-scanning feature at the robot's end-of-arm tooling to ensure that no people or obstructive contours are in the robot's range of motion.



Apart from vision sensors, the end-of-arm tooling system can include a variety of different sensors that are best suited for collecting the required data. All recorded data are transmitted to a central data analysis unit where they are analyzed using artificial intelligence.




*Mobile robotics heavily rely on a variety of different sensors, such as cameras, laser scanners, ultrasound, and other technologies.*

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# Proactive, Condition-based Maintenance and Streamlined Processes – PSI Technics Offers an Advanced Train Maintenance Solution.

## The Analytics module enhances maintenance efficiency

The optional Analytics software module can be used to evaluate the quality or deterioration of all monitored components. This enables maintenance crews to identify and systematically replace any wear-prone parts at the right time, which in turn contributes to streamlining maintenance intervals, reducing time and spare part costs and leads to increased train availability.

The scope of the Analytics module depends on the installed train inspection modules. Analytics collects and processes the data of any installed train inspection modules. For example, it can be used for:

## Determining the failure probability of every single component (predictive maintenance)

Analytics continuously analyzes newly recorded data, creating a detailed history for each component that can be used to efficiently monitor component wear. By entering additional information, such as the number of miles or kilometers traveled since the previous analysis, progressive component wear can be predicted and the remaining component lifetime can be forecast in terms of miles or kilometers. Wear parts, such as wearing strips, can be more accurately monitored and replaced in a timely manner to protect against outages at an early stage.

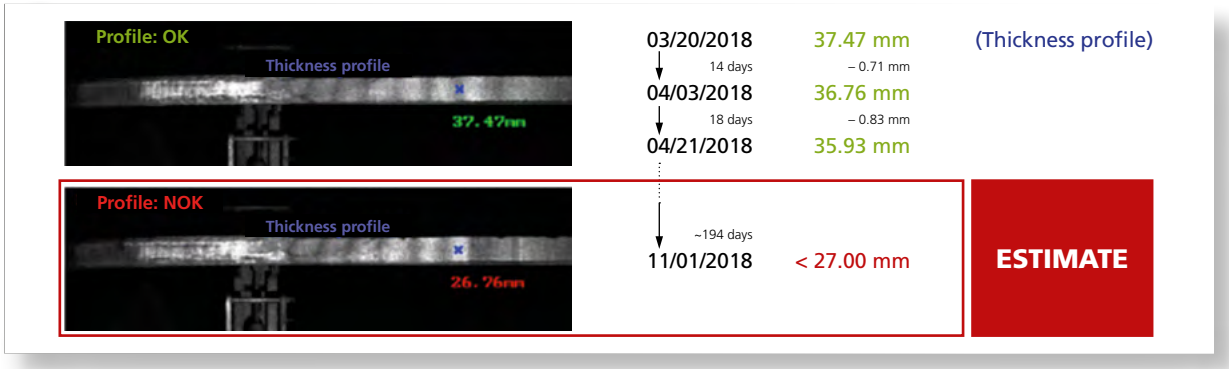
## Streamlining of maintenance intervals

The software calculates a statistical failure probability for every single component. These calculations can be used to optimize maintenance intervals based on component wear. The accuracy of the predicted maintenance intervals increases based on the volume of analyzed data. Additional information, such as traveled distances (miles/kilometers) can be included to improve the accuracy even further.

*Determining the failure probability until the next maintenance interval:*
When known maintenance intervals are combined with existing analysis data, Analytics can calculate and display the failure probability for an entire train, for example, as color-coded diagrams, percentage values, trend plots, correlation tables and more. The accuracy can be increased by prioritizing or classifying particular components as operation-critical parts to prevent potential downtimes and related costs before they happen.

*Optimizing maintenance intervals based on component quality assessments:*
Analytics can be used to evaluate the quality or deterioration of all monitored components. This enables maintenance crews to identify and systematically replace any wear- or failure-prone parts at the right time. This contributes to streamlining maintenance intervals, reducing time and spare part costs and leads to increased train availability.

***Estimated wearing strip failure:***



## We Guide You Through the Process and Ensure that Your Image Processing System Works Dependably and Consistently

**Assembly inspection and quality assessment of new or existing components**

Analytics enables maintenance crews to log, analyze and monitor new components and installation methods. Modifications to the roof/side or underbody structure of every single train can be recorded and individual train profiles can be updated to include newly installed parts, providing a detailed overview of the use of new components within the entire fleet. This allows for a direct comparison and quality assessments of new and existing components or installation methods. Newly added components can be checked for proper installation and any installed parts that are unsuitable for a particular train model can easily be identified and replaced.

**Adding performance-enhancing parameters**

In addition to the data records created by the automated train inspection system, a variety of external parameters can be used to increase failure prognosis accuracy, including those that directly impact the components' lifespan. Parameters such as weather conditions, traveled distance, velocity or component replacement and maintenance intervals for individual trains can be particularly useful.

**The cloud offers data mining and optimized data management**

Uploading train data to the cloud increases both data safety and availability. Train data and analysis results can be accessed at any time from any location. The cloud eliminates data constraints, provides a central storage location and optimized data management for huge data volumes. Data from various systems at different locations can be analyzed and used simultaneously (data mining) to explicitly highlight trends or dependencies.

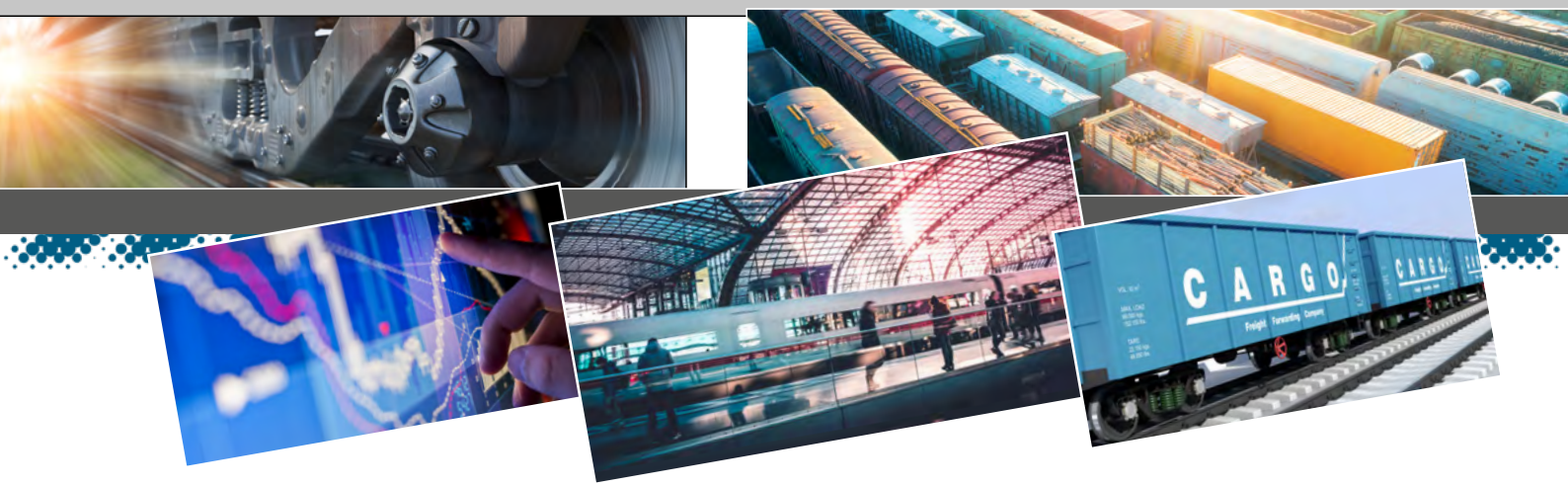
**Synopsis:**

PSI Technics delivers a turn-key system for automated train inspection that includes the required track-side equipment, cables, electrical installations, robotics, servers, web interface, client computers, track-side software, server software and any other components that are needed for optimum system performance. The project scope includes: Delivery of on-premise equipment, required accessories plus HMI/MMI interface, spare parts, maintenance tool kit, power cables, communication cables, modems and communication devices.

### The Analytics base module includes the following features:

- Failure probability calculation for inspected components
- Process optimization using dedicated hardware and software

The software learns the characteristics of each train type. The analysis is performed using pre-defined templates. The diagnostic software uses taught-in templates to automatically check predefined test components for defects or damages. This technology can be used to inspect and analyze any type of component or rail-bound vehicle.




**Technical scope of performance**

To be able to position the inspection system either close to or between tracks in a location that would be unsafe for humans, we developed an automated system based on machine vision.

**System features and highlights:**

- Safety-critical warnings are transmitted in real time after the train passes the inspection system (recipients can select the required warning messages)
- Automated delivery of data, pictures, alarms and reports. Easy to understand inspection summaries and error codes
- When the train passes the inspection system, the system records time, date, train speed, the number and the distance of passing axles, the total number of vehicles, cars, locomotives, the vehicle position starting at the front of the train, the travel direction and the type of rolling stock
- Software for data collection and storage and for displaying maintenance reports that are transferred by track-side equipment
- Modular structure
- Self-diagnostic features
- Compliance with all major rail standards
- 24/7 availability
- The system is designed and installed in such a way that system operation will not affect rail traffic in any way
- Self-learning system. Performance optimization is based on recorded data about wear and defects. The system uses an international standard library that includes wide variety of potential defects, for example, wheel truck/bogie, underbody, wheel or brake gear defects
- Integration of RFID readers for automatic vehicle identification
- The system does not affect signaling equipment, track circuits or other devices that are installed near the tracks or at switchyards
- Web-based train reports: Clients for the use of desktops, laptops, netbooks and smart phones, password-based access for authorized personnel (for data and report entry, editing, viewing and downloading of information) as well as user privileges for different user levels are provided
- Reliable, networked alert management software with a variety of analysis and diagnostic features
- Automatic detection of incoming trains. Recording sensors and cameras are switched on automatically when a train approaches the system
- When no trains are present, sensors and cameras are automatically switched off to save power
- Automatic detection of train/rolling stock number and other relevant markings
- Manual MMI/HMI interface
- Data transfer connectivity, operation and maintenance of back-end servers
- Complete TCP/IP support for a seamless integration into existing rail data networks
- Possible integration of third-party systems
- The system supports both travel directions
- Mobile inspection with the help of robotics
- All-weather operation (operating temperature range: –20 ˚C to 60 ˚C (–4 ˚F to 140 ˚F), up to 100% humidity
- Trainings include operator training, troubleshooting, maintenance of optical, mechanical, electrical and electronic system components as well as software training.

# Conclusion: Reliable Image Processing Systems Guarantee Operational and Process Stability

## Benefits of automated train inspection:

- Counteracts the effects of demographic change
- Counteracts the shortage of skilled labor
- Reduces the staff's workload (e. g., no pit work is required)
- Reduces costs for manual inspections
- Provides objective results and increases safety
- Increases continuity across processes
- Proactive and condition-based maintenance frees up the track in the maintenance shop for other tasks
- Analytics and IoT solutions ensure automated monitoring (predictive maintenance)
- Identification of defects and creeping wear
- Data and maintenance locations are networked to enable data mining
- Machine learning enables continuous maintenance optimization
- Efficient process optimization throughout the entire value chain
- Increased environmental sustainability, operational safety and profitability

## OUR SERVICES

We assist you every step of the way – from developing the image processing concept to completion. We focus on a close cooperation with our customers to provide solutions that are tailored to their needs.

We offer in-depth consultations and evaluate and assess the project requirements on site. We develop prototypes for integrating the ideal camera solution and safely commission the system. We guide you through the process and our maintenance experts ensure that your image processing system works dependably for years to come.

Automated train inspection with image processing technology opens up new possibilities for improving the safety and reliability of your rolling stock.

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# AUTOMATED TRAIN INSPECTION

We are convinced that your company will benefit from automated train inspection and would be happy to discuss the details of a custom solution with you. Contact us today to schedule an appointment for a personal consultation.

Trains are the future of climate-friendly mobility. Products from PSI Technics contribute to a safer and more reliable train operation.

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