During the past five years, different technologies, for example fiber optic sensors using technologies such as Fiber Bragg Grating (FBG) and Distributed Acoustic Sensing (DAS) gained increasing interest within the railway industry. Several tests and trials regarding proof of concept, reliability and safety standards were performed by various railroad companies. As a leading supplier of sensor technology for railway applications, Frauscher Sensor Technology is aware of such trends and continually investigates innovative sensor technologies to improve detection and monitoring with less effort and costs. True to this basic philosophy, only DAS revealed comprehensive potential to become a base technology for various specific railway applications.

Fascinating results
Appropriate tests have been made on tracks of Transportation Technology Center, Inc., and CSX, as well as in various countries all over the globe, such as Australia, Germany and the United Kingdom. Besides comprehensive train tracking and asset condition monitoring capabilities these projects revealed the ability of DAS-based systems to track people, monitor work groups, detect trespass, protect infrastructure and more. On that base a substantial number of applications in the areas of train tracking, asset condition monitoring and security of people and infrastructure have been carried out. Whereas the realization of complex and safety relevant applications in the fields of train tracking and asset condition monitoring still needs further development, full wayside security solutions are already available.

As a worldwide expert for sensor technologies used on railways, Frauscher has started a comprehensive and highly focused research and development program to make DAS ready for the railway industry. This program comprises various concepts, which include starting to enhance the DAS system and to provide a rail-specific Human Machine Interface (HMI) that displays data in a proper way and enables appropriate reactions to tracked events.

Principle of DAS
The principle of DAS is based on the ability of detecting changes in intensity of light reflections caused by sound waves radiating against a single-mode fiber optic cable as
shown in Figure 1. A coherent laser is pulsed into this fiber at a set frequency. Natural impurities within the fiber cause a small portion of light to be reflected back to the source, which is called backscatter. The intensity of the reflected Rayleigh backscatter is measured as a function of time after transmission of the laser pulse, translating to physical changes in any given fiber section. These changes can be caused by structure-borne sound and vibrations in the vicinity of the fiber optic cable. Classification algorithms have been developed to alarm the user for various activities that cause measurable signatures, such as movements of vehicles, footsteps of persons or activities, for example manual and machine digging. These capabilities of DAS are in use in the oil, gas and border/area security business, where it is a proven concept for monitoring infrastructure and to carry out various security applications.

Limitations of DAS
Although the basic idea behind these operations is the same as for the use in other industries, it is not possible to use exactly the same systems and the same approach in the rail sector. First, tracking of trains is a special application with no similarity within the existing applications outside rail. Following a train continuously over hundreds of miles without interruption and filtering out all the different impacts along the route is a very challenging and unique task. Second, railways do have their own standards and requirements, which differ between or even within national areas and must be considered to provide appropriate solutions. None of the currently available DAS systems addresses rail-specific requirements and standards. Considering all these factors reveals three main limitations of DAS in the railway industry:

- **Track ID:** Up to now, there is no possibility to identify if the impacts are on or near the track. It is also difficult to define, on which track a train is moving within multi-track areas and nearly impossible in even more complex track layouts.
- **Accuracy:** DAS does not yet have the proven capability to detect individual axles in a robust or fail safe manner, which is affordable for train integrity over long stretches of a network.
- **CENELEC compliance:** In existing DAS-based solutions, no basic developments and processes were generally fulfilled to create a solid foundation for SIL applications. Also the limitations regarding track ID and accuracy have to be solved to fulfill criteria regarding CENELEC.

Frauscher Tracking Solutions
Having learned more about what is possible and what is not by using DAS on railroads, Frauscher combined results from various test installations with knowledge that was gathered in close co-operation with operators and companies who have worked with this technology for years. On that base, Frauscher started initial developments for railway-specific adaptions of existing DAS systems.

The company’s own DAS experts work on technological developments to meet the industry’s specific requirements. These include for example maximum resolution for specific applications, as well as transmission and storage of data. Increased insights and research enabled the development of first generation algorithms to enable the detection of specific events and asset condition, such as rail breaks and wheel flats. Adjustments that have been made to allow these first fundamental steps still need further improvement of hardware and software. However, the outcome of this process – the Frauscher Acoustic Sensing (FAS) – is now available for some basic applications.

Capabilities of FAS
FAS enables an accuracy of detection up to 30 feet along the fiber and also provides the corresponding route mileage or GPS coordinates of detected activities. Depending on the resolution, one FAS-laser unit is able to monitor up to...
In the past, various security monitoring applications re-

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Security applications

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tracking, it delivers the position of the train, velocity, ac-

celeration, driving direction, length of train and more. This

enables efficient handling of timetable management, train

speed management, arrival announcements, as well as sup-

porting train localization. In the area of asset condition

monitoring rail breaks can be detected, as well as wheel

flats, loose track joints or vibrations from a catenary flash-

over and rock falls or landslides.

By developing FAS a range of adaptations has been carried

out on existing DAS-based approaches to create a base for

the use of this technology within the rail industry. However,

by implementing these adjustments, not all limitations as

above have been resolved yet. It is clear, though, that FAS

can provide benefit now, and as the years progress addi-

ional capabilities can be added.

Human Machine Interface

Having created a system that generates a wide range of infor-

mation, Frauscher has also focused on how to transmit this

data to other systems and/or present them to the system users

in the back office. As described above, FAS is able to provide

railway operators with a wide range of information. The sys-

tem’s output consists of a considerable amount of data that

has to be sorted and structured to allow useful processing.

This is enabled by a newly developed Human Machine In-

terface (HMI) that provides clearly arranged delivery of data

and allows the translation of specific data to reports and alerts

that can be used in individually defined processes.

This knowledge and concept was also considered when de-

veloping FTS and enables simple implementation in interlockings, diagnostic systems, management

systems and more.

Security applications

In the past, various security monitoring applications re-

quired individual systems, which made a single point of

surveillance and integration expensive and complex.

Moreover, installations were short-range and needed to be

handled on a local level, which was both costly and in-

efficient. Security patrols are often employed to conduct

random checks at all points on the network. The ideal se-

curity system installed for railroad use should address sev-

eral minimum requirements: the ability to detect trespass-

ers railroads and transit agencies the opportunity to install

an all-in-one security system which can expand the reach of

rail network surveillance for a relatively low-cost and in one

simple package. Using a proven technology protecting oil and

gas pipelines and now adapted especially for the rail environ-

ment, the DAS principle is employed to detect activities for

a distance of up to 25 miles from a single monitoring point.

A network of FAS sensors enables it to provide a security

capability across a client’s total network.

25 miles of track with whole networks being monitored by

multiple FAS units. Based on pilot installations and close

cooperation with operators, individual categorization of

events that are tracked is possible in order to generate spe-

cific alarms and reports.

As a stand-alone solution, FAS can be used for non-

vital track training, basic applications in asset condition

monitoring, as well as security applications. Used for train

tracking, it delivers the position of the train, velocity, ac-

celeration, driving direction, length of train and more. This

enables efficient handling of timetable management, train

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terface (HMI) that provides clearly arranged delivery of data

and allows the translation of specific data to reports and alerts

that can be used in individually defined processes. Signals from

the FTS system are collected, categorized, displayed and can

also be provided to mobile devices via text message or even by

drones that can be sent to appropriate locations. This enables

the quickest possible reaction to any activities on and near the

tracks. Additionally, interfacing with IT networks is enabled.

Collaborating with system integrators and railway opera-

tors all over the world has convinced Frauscher that it is cru-

cial for future oriented products to be able to provide approved

individual operator interfaces. This knowledge and concept

was also considered when developing FTS and enables simple

implementation in interlockings, diagnostic systems, manage-

ment systems and more.

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quired individual systems, which made a single point of

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A network of FAS sensors enables it to provide a security

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Based on FAS, Frauscher Tracking Solutions (FTS) of-

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ment, the DAS principle is employed to detect activities for

a distance of up to 25 miles from a single monitoring point.

A network of FAS sensors enables it to provide a security

capability across a client’s total network.
Developing combined solution
A second and parallel concept study at Frauscher includes the integration of DAS with axle counter and wheel detection information or even to combine axle counters with DAS systems. These ideas will compensate for the limitations mentioned above. Especially if it should be possible to detect each axle in a fail-safe way, the DAS system resolution must be very high. Thus, there will be disadvantages regarding costs, as higher resolutions reduce the length of track sections that can be monitored by one unit – and as a result, more data will be generated that has to be handled in real-time. It is expected that integrated solutions will be available sooner than SIL conforming DAS systems.

FTS-FAS+
To reach the next level of data quality when using DAS in the railway industry, FAS has been designed to enable combined solutions consisting of optical sensors and position sensors. Overlaying data from both approaches increases the possibilities of proceeding with information generated by the FAS+ significantly.

FTS-FAdC+
The most advanced combination consists of FAS and a modern axle counter, such as the Frauscher Advanced Counter FAdC. In this constellation the FAS provides valuable data to enable carrying out of complex and safety relevant applications, as the axle counter operates on a CENELEC SIL 4 level.

This solution also has the potential to be used in challenging areas, such as long and remote block sections. Due to the fact that axle counters can be used on small track sections, as well as on long block sections and FAS is able to monitor up to 25 miles per unit, this combination can now provide those areas with fail-safe train detection, train localization and rail break detection.

Conclusion
The new approach with Frauscher Tracking Solutions FTS will be the only track-based technology, which allows a permanent train location without any technology on the rolling stock. It does not matter which trains are moving in the network or if they have the right on-board equipment. This reduces the number of systems and components onboard, as well as on-track, significantly and simplifies traffic management and interoperability. Sooner or later continuous train detection via one single trackside solution will be available also with regards to the required quality, reliability and safety. These capabilities and massive reduction of complexity and costs improves existing requirements and opens up exciting new ideas and concepts for train control and traffic management.