Safety System for Track Maintenance Vehicle Operation of Shinkansen

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1 Introduction

Shinkansen operations require the utmost safety. To date, we have a history of zero passenger fatalities. The Shinkansen has no record of major accidents during its 46 years of service since its inauguration in October 1964. This success is attributed to extremely high safety standards.

Our safety strategies include the following:

1) Control the operation and prevent trains collisions by ATC (Automatic Train Control) system,

2) No railroad crossings which make no contact with roads,

3) Exceptionally robust components for nonredundant systems and, lastly,

4) Solutions to optimize maintenance service.

This paper describes our approach of the last task.

2 Separation of Train Operation and Maintenance Work

First we focused on the maintenance activity on the railway track. The Shinkansen maintenance requires extensive maintenance equipment, and it operates at speeds up to 275 km/h. Therefore it was easy to predict that the collision between the train and the equipment would cause major damage. To eliminate such potential accidents, we have implemented the simple policy of separating 'train operation hours' and 'maintenance service hours' as shown in Fig.1.

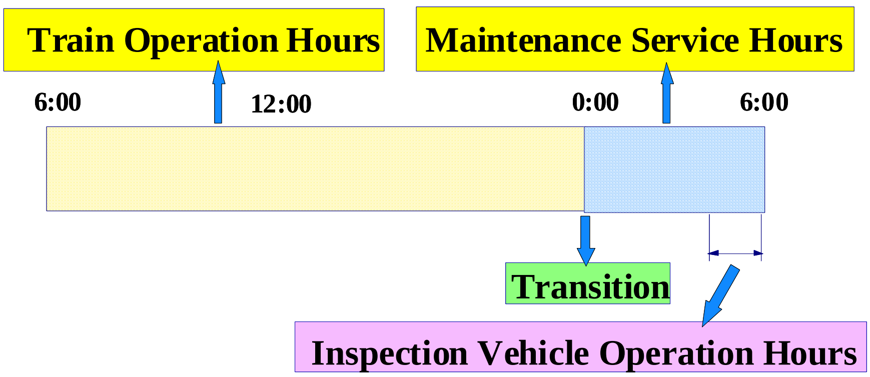

Fig.1 Track Schedule

It shows the schedule for one full day, showing the allotted times for train operation and maintenance service. The intensive maintenance service on railways is performed during the hours when trains are not in service.

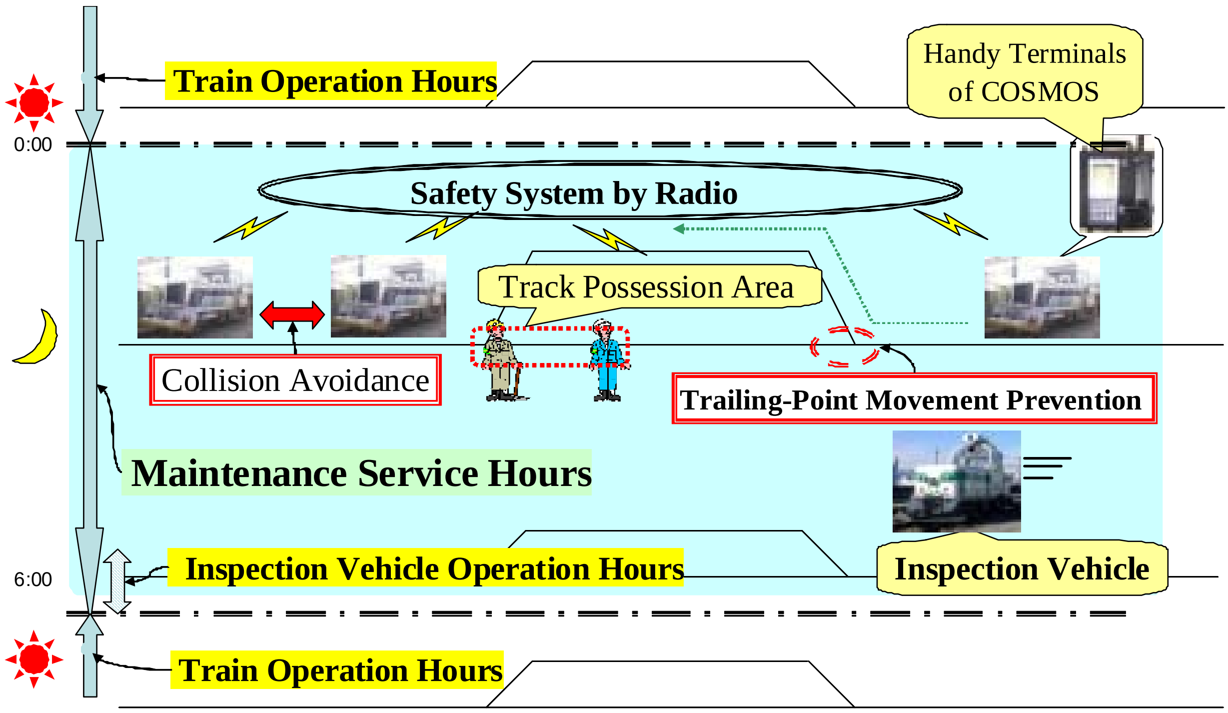

Fig.2 Maintenance Service Hours

As shown in Fig.2, it is feared that hazardous accident as the below might occur in maintenance service hours.

(1) Maintenace trains collisions

(2) Trailing-point movement in a station yard

On the other hand, it is feared that the next risks exist just around the same time as finishing the maintenance service hours and starting the train operation hours.

However, despite the precaution taken to separate train operation and maintenance service hours, there remains the risk of a train running into the maintenance equipment accidentally left behind on the railway. In order to prevent such danger, the special motor cars, called an "inspection vehicle," are operated to find and collect the obstacles.

As the result of these inspection vehicle operations, both the service, train operation and maintenance service, have been successfully completed.

3 Development of Inspection Vehicle

Fig.3 Conventional Inspection Vehicle

Fig.3.the shows conventional inspection vehicle. In addition to the human operator's visual inspection of the track area before him, a sensor at the lower front end of the vehicle detects any obstacles including maintenance equipment on the track.

We sought improvements in the inspection vehicle for the following reasons:

(1) Since trains have become faster, the volume of the maintenance work has increased. However, it is difficult to allocate more time for the maintenance service as the operation of the inspection vehicle takes up a large portion of the available time.

(2) Because of the night work, it is becoming difficult to secure the necessary number of personnel for station, maintenance and construction services.

(3) The labor, repair and other costs required to operate the inspection vehicle are considerable.

For these reasons, we began developing a "new type of inspection vehicle" to enable automatic operation and detection of obstacles on tracks in 1991. In December 1995, we completed a prototype which integrated component technologies. Rework including a number of performance tests conducted on the Joetsu Shinkansen tracks. After determining the final specifications for the production model, seven units were introduced for the Nagano Shinkansen in October 1997, which have been running smoothly since.

Fig.4 Final Automated Obstacle Detection Vehicle currently in Use

3-1 Features of New Inspection Vehicle

The new inspection vehicle has two key technologies which are the "Obstacle detection system using computer image processing technology" and the "Built-in automated control system".

3-2 Obstacle Detection System

The purpose of this detection system is to detect obstacles on the track automatically by surveying the area in front of the vehicle by means of computer image processing technology to decipher the visual information. It consists of a searchlight, a CCD camera, a computerized rail tracking system and a track database.

This is a system that replaces visual checks for finding tools and other objects left on the track after work by combining technology for detecting obstacles 400 m ahead through image processing with onboard autonomic self-driving vehicle technology.

3-3 Built-in Automated Control System

Shinkansen trains can operate at high speeds safely, due to the installation of an automatic train control system which controls the train speed taking into account the distance to the preceding train and also the train route data. In contrast, maintenance vehicle have no such automatic safety guarantees and rely on human attention and reaction which significantly limits the speed at which the vehicle can safely travel.

To increase the efficiency of the inspection vehicle providing safely completed inspections within the 3:30 to 5:50a.m. allotted time slot, the following functions were automated:

(a)Pulses generated from the vehicle's drive units are read to determine the vehicle's speed. In addition, ground equipment installed every kilometer updates the car on its location.

(b)Inputting the distance information from (a), the vehicle runs at a speed computed by referring to the track data for the location information.

(c) The system automatically stops the vehicle when it detects an obstacle.

This total automated system is classified as on-board and self-sufficient. Its network (Fig. 5) consists of an automated operator system, cab console buttons and levers, and automatic monitoring system all linked to the drive and brake commands.

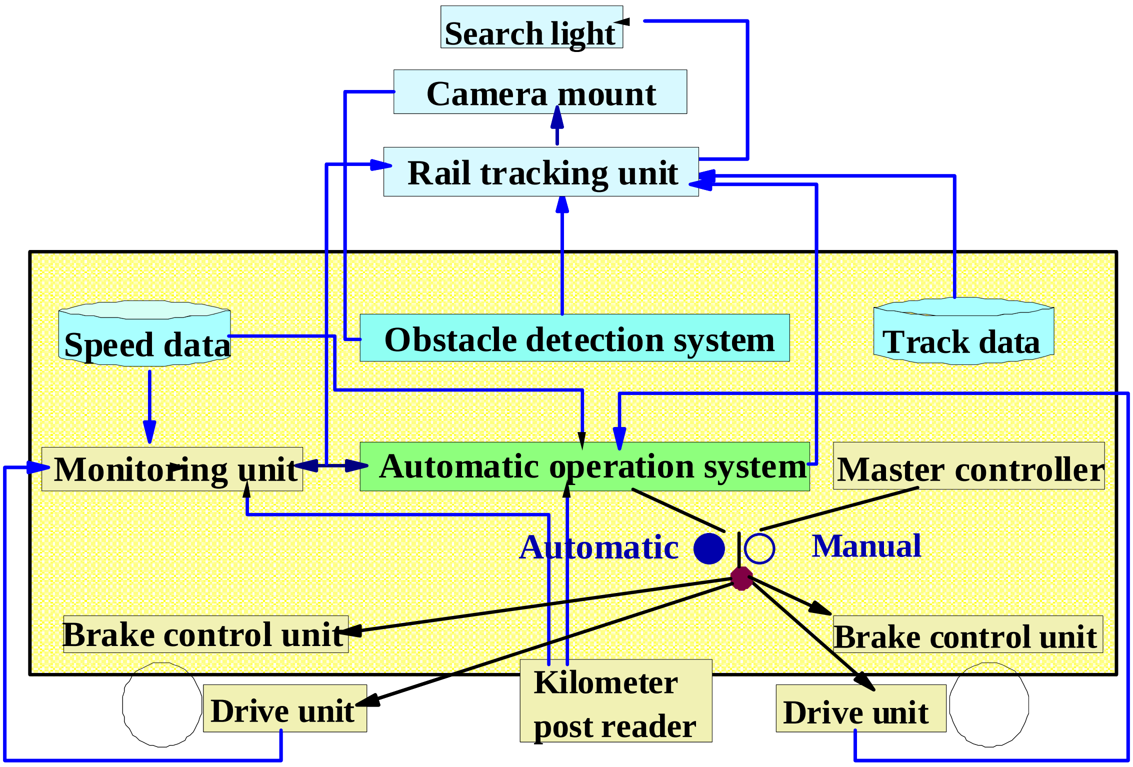

Fig.5 Architecture of On-board System

4 Flow of Maintenance Work of Shinkansen

In the Shinkansen, we make it a rule to completely separate "train operation hours" and "maintenance service hours" in order to ensure safe train operation. In "maintenance service hours", we perform maintenance service on railway tracks with track maintenance vehicles or with track possession. For example, carrying rails and ballast, grinding rails, detecting rail flaws and inspection of overhead wire are performed with track maintenance vehicles, inspection of turnouts and replacing ballast are performed with track possession. With dense traffic and increased speed of trains, the work with track maintenance vehicles has increased. Recently, at a high season, up to 10 track maintenance vehicles go to work from a same maintenance base. Therefore, there are many vehicles in maintenance service hours.

We describe a flow of track maintenance work with track maintenance vehicles as follows.

(1) In maintenance base, we prepare work and wait to start “maintenance service hours”.

(2) “Maintenance service hours” start, we go through procedure for entering main line, and going to the main line.

(3) After we enter the main line, we go to the work place and work. If we need to enter a station, we stop in front of the station, then we go through procedure for entering the station and getting our route. After those procedures, we go into the station.

(4) In the station, we go carefully because we must stop in front of crossing and check our route.

(5) In the work place, we work with track maintenance vehicles. If necessary, we couple or divide of vehicles.

4-1 Background of Development

Under the situation as already described, two collision accidents with track maintenance vehicles had happened. One had happened at Tokaido Shinkansen in JR Tokai on 6 August 1993, and another had happened at Sanyo Shinkansen in JR West on 3 September 1998. In the former accident, Shinkansen operation stopped up to a half a day which caused 169 services cancellation, and in the latter accident 3 persons were injured.

Though the accidents did not happen in our company, we could not say that the collision between track maintenance vehicles never happens. We must prevent such accidents, so we started to develop "Safety System for Track Maintenance Vehicle Operation of Shinkansen".

4-2 The Function of Safety System for Track Maintenance Vehicle

We developed this system to prevent track maintenance vehicles from collision accidents, therefore we need this system to stop a track maintenance vehicle at a dangerous situation. Moreover, it must avoid unnecessary warnings, and be relied by an operator of a track maintenance vehicle. Therefore, we designed this system which consisted of three functions.

(1) Position, speed and direction sensing of the track maintenance vehicle.

(2) Data communication with nearby track maintenance vehicles and transceivers of nearby track possession area by radio.

(3) Provide warning by calculating relative distance and relative speed with another vehicle, and provide automatic braking even if the operator does not apply.

Fig. 6. describes each function of Collision Avoidance.

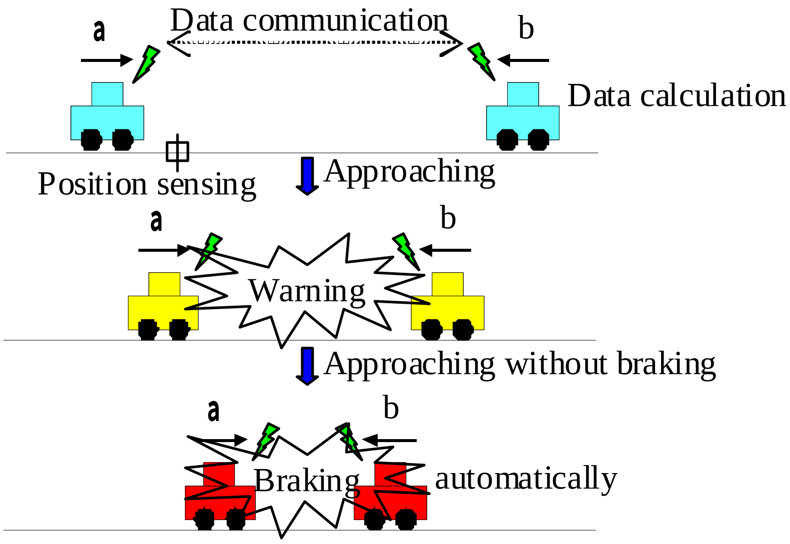

Fig.6 Function of Collision Avoidance

4-3 Achievement of Position Detection Function

The essential position detection method of this system is shown in Fig. 7, a method of combining position correction with speed pulse and ground coils. The Safety Research Laboratory used this automatic operation system to develop the new inspection vehicle. Moreover, position detection sufficiently senses a high accuracy.

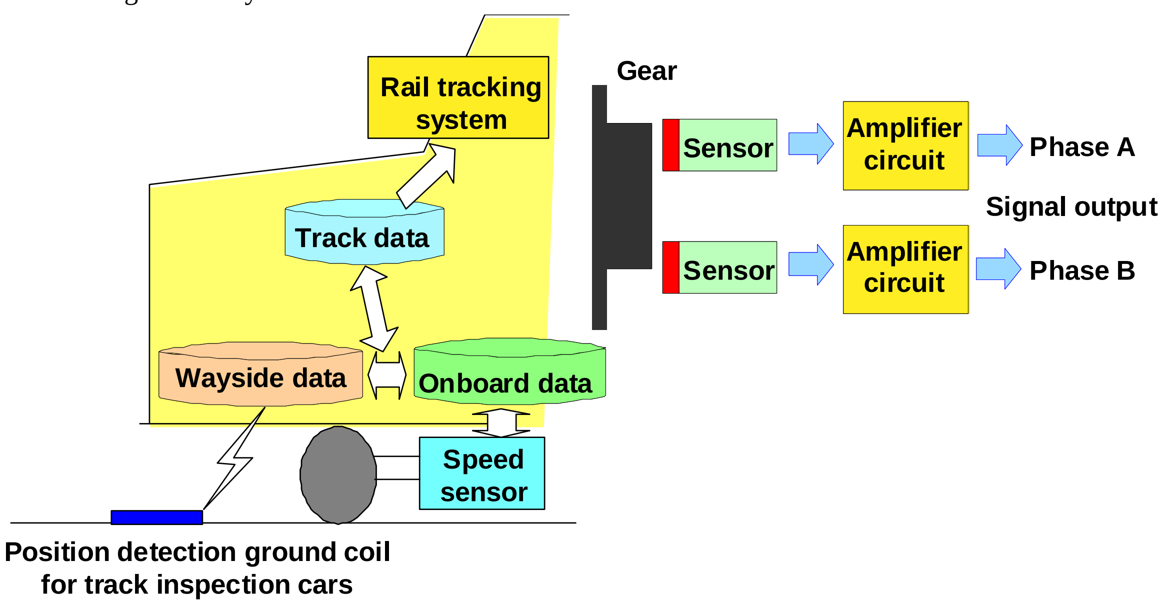

Fig.7 Position Detection System for Inspection Vehicle

4-4 Data Communication by Radio

This Safety System is communicated by TDMA without a base radio station and each transceiver synchronizes the communication based on PPS signal of GPS. The communication cycle is 2 seconds, and 1 cycle consists of 18 slots. So, a transceiver can communicate simultaneously with other 17 transceivers. Even a high season, up to 10 track maintenance vehicles go to work from a maintenance base. So, all slots aren't filled with transceivers.

4-5 Development of a Trailing-Point Movement Prevention Function

Our collision prevention function has been introduced to all Shinkansen maintenance vehicles by fiscal 2003. However, the direction of the opening to traffic is confirmed according to human attention, therefore the possibility of trailing-point movement leading to derailment remains. We thus started to develop a Shinkansen maintenance safety system with the trailing-point movement prevention function that prevents trailing point movement to further increase safety since 2005.

The system imports routing information from handy terminals of COSMOS, and it determines how far the maintenance car can proceed based on the line database including turnout positions and kilometerage. If a maintenance vehicle attempts to enter a non-approved area, the system outputs an alarm and braking signal to stop the vehicle.

As shown in Fig. 8, the area that can be entered in the yard track layout is displayed on the cab monitor.

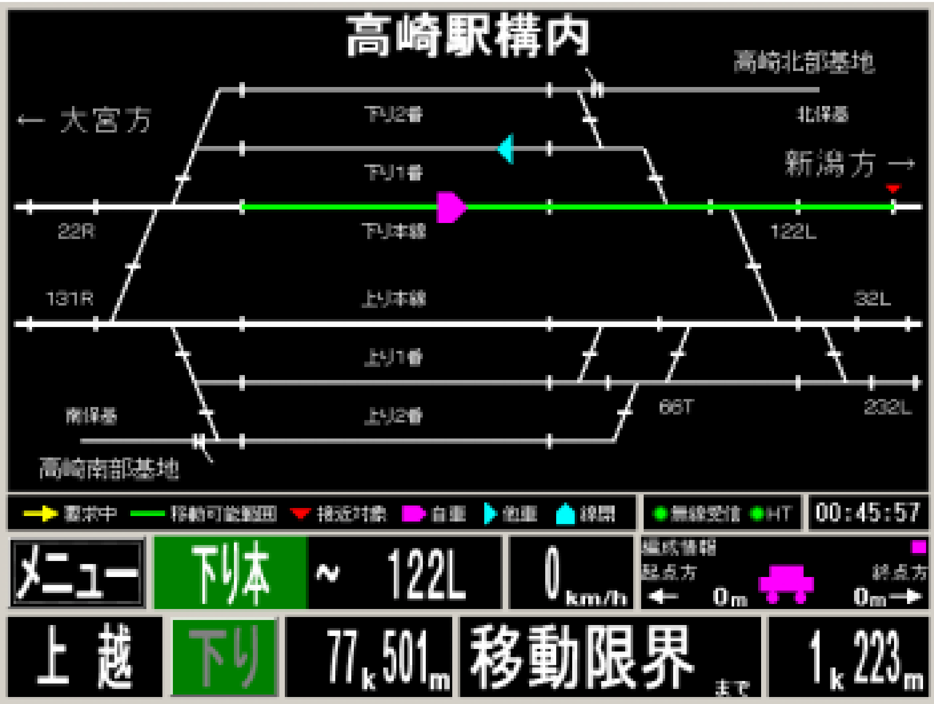

Fig. 8 Example of Cab Monitor Display

Visual display on the cab monitor constructs a human-machine interface based on the concept that increasing visual information for the operator prevents human errors.

The system with point movement prevention function has been introduced to all Shinkansen maintenance vehicles since the end of fiscal 2006.

5 CONCLUSION

We developed "Safety System for Track Maintenance Vehicle Operation of Shinkansen" and installed it on Tohoku, Joetsu and Nagano Shinkansen. This system can stop a track maintenance vehicles appropriately before the collision occurs. This system is trusted for the operators of a track maintenance vehicle with its reliable warning and automatic braking.

The system has been preventing track maintenance vehicles from collision accidents, and contributing to safety in track maintenance works of Shinkansen in JR East area.

Moreover, not only conventional inspection vehicles but also new inspection vehicles we developed were introduced to all Shinkansen tracks in 2005, and have been stably operated in JR East area since then.

We have been currently under development a new type of transceiver with easily viewable display to prevent from accidental contact between maintenance workers and maintenance vehicles or the inspection vehicles travel at 90km/h in maintenance service hours.

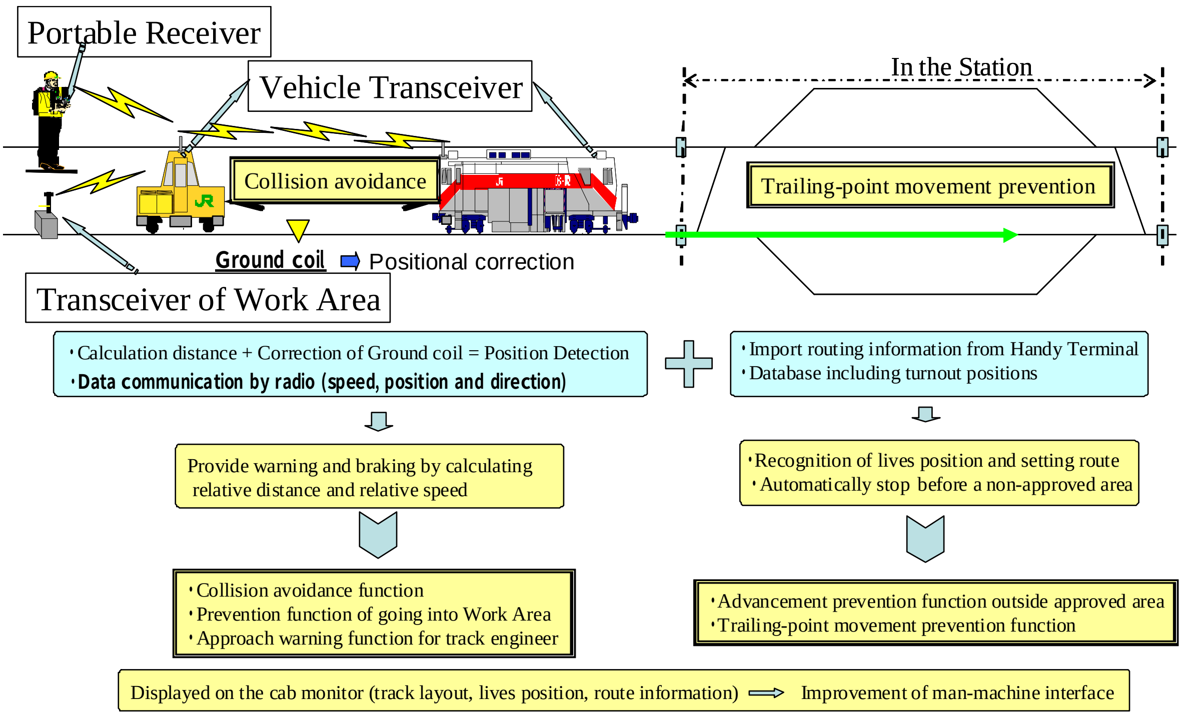

Fig. 9 Outline of This Safety System.