A Project Report on

Kavach Train Collision Avoidance System (TCAS) - An Indigenous ATP System

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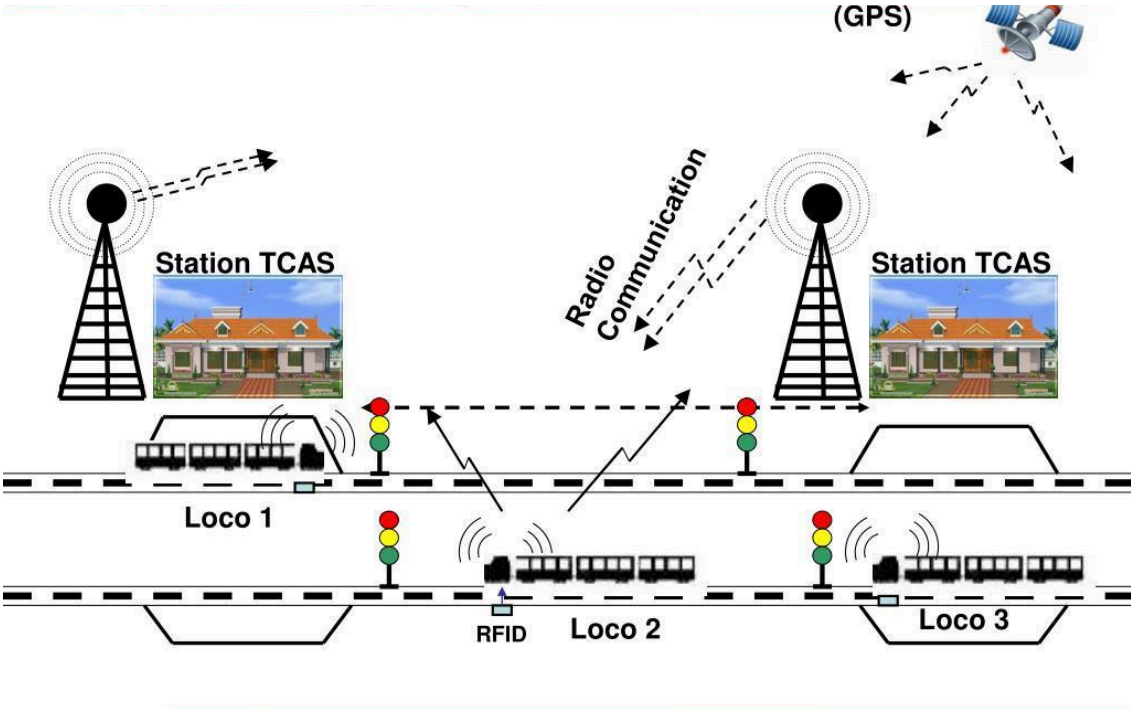
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Introduction



Safe and incident free operation of trains not only results in satisfied customers but improve the productivity of costly fixed and movable assets, viz. track, OHE, signaling systems, locomotives, rolling stock and human resources. Automatic Protection System (ATP) contributes to achieve above objectives of a transport system.

KAVACH is an indigenously built Automatic Train Protection system that aligns with the Hon'ble Prime Minister's vision of "Aatma Nirbhar Bharat" and the "Make in India" campaign. KAVACH would enhance Indian Railways by improving its performance in a cost-effective manner by improving both safety and efficiency.

Train Collision Avoidance System KAVACH is an ATP System validated to SIL 4, highest level of Safety Integrity, developed by RDSO. The system alerts the Loco Pilot while approaching the signal about their aspects, Permanent Speed Restrictions (PSR) and requires him to acknowledge the warning in case of over speeding. In case the Loco pilot does not respond, the system initiates the brake application after a pre-defined delay.

Salient features of the system are as follows:

· System is interfaced with existing signaling system and provides continuous update of Movement Authority.

· Prevention of Over speed: Section Speed & Loco Specific Speed

· Displays aspect of Signal on the DMI in the Locomotive

· Manual SOS facility both from Loco and from Station in case of emergencies

· Prevention of Side-collision, Head on collision, Rear end collision under certain specified conditions.

· Protection of roll back/ forward and reverse movement.

· Automatic whistling in the approach of LC Gates.

System Overview

The brief overview of functioning of TCAS is as given below:

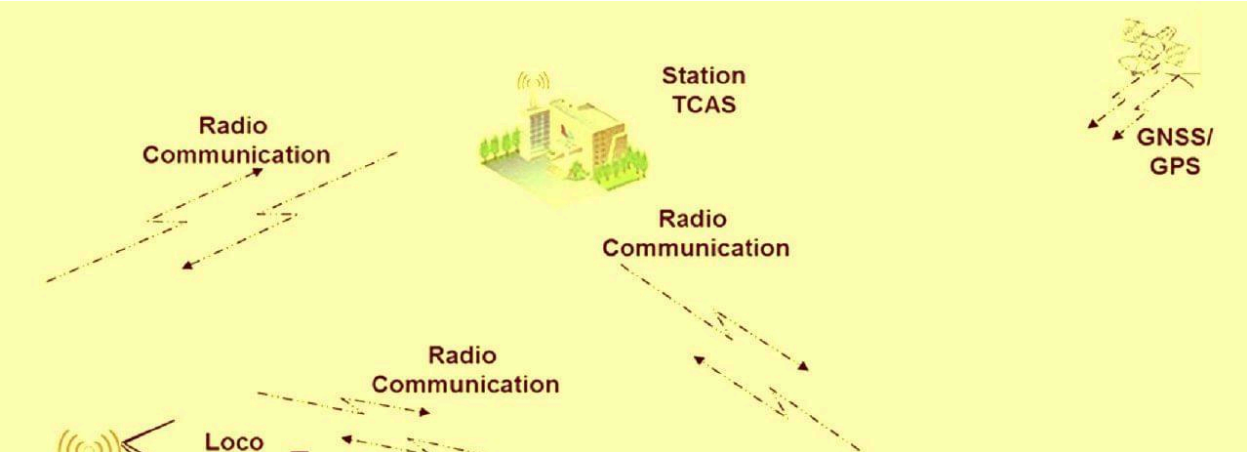
TCAS trackside subsystem comprises of RFID tags mounted on track in station and block sections to provide Trackside information to the Loco TCAS unit installed in the locomotive.

Track Identification Numbers (TIN) are issued to sections of track, including berthing tracks, point and block sections. The TIN and RFID tags are utilized to evaluate the direction of the train.

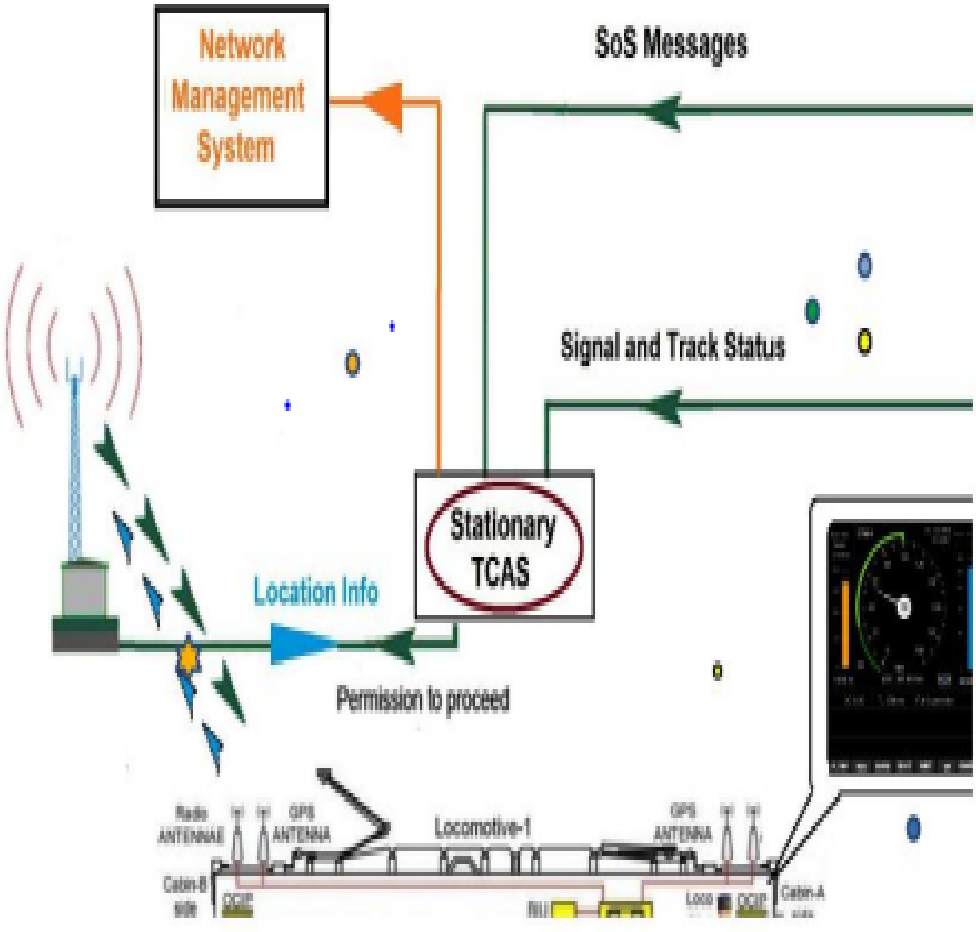
To communicate with the locomotives in the station area, the system additionally includes a stationary TCAS unit that is situated at the station with radio tower. Stationary TCAS interfaces with station interlocking to get real-time dynamic information on signaling, such as various signal aspects.

The TCAS Control Table (excluding shunt signals and overlaps) is used to specify the route information of all the signals, monitored by a particular stationary TCAS unit. Through UHF radio communication, the stationary TCAS unit receives real-time information on the locations, speeds, etc. of the trains under its supervision. If the Mid-Section interlocked Level Crossing Gate and Intermediate Block Signaling (IBS) sites are not within the coverage of the station radio tower, a separate Stationary TCAS unit is provided. Remote Interface Unit (RIU) should be employed when remote signaling functions must be fetched to a nearby Stationary TCAS unit, such as end cabins/distributed interlockings or LC gate/IB falling inside radio coverage of station tower. The onboard Loco TCAS unit installed in the locomotive detects the location of the train using an RFID reader to read pre-programmed RFID Tag data. Before identifying the direction, the loco TCAS unit sets its absolute location (approaching signal distance from the train position) and TIN to undefined (zero). When the Loco/Train has passed two RFID tags successively with Absolute location, the direction of movement of the train should be identified. The Loco TCAS unit estimates the train's location between two RFID tags dynamically depending on the distance travelled from the last RFID tag via the Locomotive's speed sensor arrangement. Upon passing through the RFID Tag, the Loco TCAS unit broadcasts the train's location and direction to the Stationary TCAS unit through the UHF radio antenna provided in the locomotive. The Stationary TCAS unit must use the direction of movement of the Loco/Train to locate the approaching signal of the Loco/Train. Stationary TCAS unit shall then calculate the movement authority based on the signal aspect or/and track circuit status or/and route locking status, point position and the status of the berthing track circuit. Stationary TCAS unit shall then transmit the Movement Authority to the Loco TCAS in its jurisdiction in station area. The signal aspect of the approaching Stop Signal determines the length of the movement authority. Based on movement authority, speed restriction, and other information received from the Trackside sub-system, the Loco unit must build speed profiles/brake curves for various scenarios. The Loco TCAS unit should show to the loco pilot the train speed, permitted speed, target distance, and target speed through a Driver Machine Interface (DMI). If an approach signal is Red (Danger), the Stationary TCAS unit must convey this information to the Loco TCAS and lower the movement authority to zero. If the loco pilot fails to stop the train, the brakes will be applied automatically, eliminating Signal Passing at Danger (SPAD). In the event

of a conflict between signal aspect, point position, berthing track section, signal aspect sequence, and TIN, the Stationary TCAS unit must transmit the more restricted aspect of that signal and lower movement authority suitably. Train collisions in the station section are therefore avoided. In the event of a block section, if Stationary TCAS detects two trains approaching each other on the same TIN, Stationary TCAS will create the SoS instruction for both trains. When such a Loco specific SoS is received from a Stationary TCAS Unit, the trains are automatically stopped. In the event of an emergency, there is also a facility for sending SoS messages from Loco TCAS to other Loco TCAS. Full Duplex UHF Radio Communication through Multiple Access TDMA/FDMA method is the communication technique adopted for information transfer between Stationary and Locomotive units in the station area. A particular frequency pair is assigned to a station for communication between Stationary TCAS and Loco under its jurisdiction. Loco TCAS units may also interact with other Loco TCAS units in the same block section, station area, and in emergency circumstances (SoS, head-on, rear-end collisions) by using a fixed frequency (f0) within its assigned time slot. Network Monitoring System (NMS) with a central server at divisional office must be provided via OFC Network for centralized monitoring of TCAS equipped Trains and Stations within the network. The transmission of exceptional fault/critical messages from Stationary TCAS and Loco TCAS to NMS is done using the relevant GSM interfaces. NMS is used for error event troubleshooting, off-line simulation, real-time monitoring of TCAS loco, and so on. Radio Communication in the TCAS System must employ cryptographic mechanisms to transfer messages between Loco TCAS and Stationary TCAS units. Stationary TCAS and Loco TCAS acquire authentication keys for secure communication via GSM/GPRS communication through a Key Management System (KMS). Real Time Clocks (RTC) of all the TCAS systems are synchronized with GPS/GNSS.



TCAS Schematic



TCAS Functioning Schematic

Summary of TCAS Functioning

Requirement	Mechanisms
Direction of Trains	Comparing Absolute location of two RFID tags passed by train
Location of Trains	Distance traversed beyond a RFID tag on Track Sleeper (Rail-road Tie) through speed sensing arrangement (Tachometer)
Extraction of dynamic Signaling information	Interfacing to station interlocking (PI/RRI/EI)
Loco to Loco message broadcast (non-SIL-4)	In block section, in station area and in emergency situations (SoS, head-on, rear-end collisions) using a fixed frequency (f0) in its designated time slot
Prevention of over speed and SPAD	By reducing the movement authority based on the aspect of approaching signal.
Centralized monitoring of TCAS equipped trains and stations	Through Network Monitoring System (NMS)
Real Time Clock (RTC) synchronization	Through GPS/GNSS

Operation Functions of TCAS

1.Information received by Stationary TCAS unit from Loc TCAS unit

- Direction of train movement
- Location of train
- Emergency messages

2. Information received by Stationary TCAS unit from interlocking

- Approaching Signal aspect (ECRs)
- Berthing track circuit status (TPRs)
- Point status (NWKRs/RWKRs)
- Route locking status (UCRs)
- Status of block instrument Line Closed condition

3. Information received by Loco TCAS unit from Stationary TCAS unit

- Aspect of the approaching signal on route.
- Distance between the approaching signal and the train position (absolute location).
- Approaching signal identity.
- The next signal aspect and its distance in the region of the same stationary TCAS unit, if the signal on approach is turned off.
- Movement authority (the distance for which the train is authorized to travel).
- Static Speed Profile.
- Temporary Speed Restrictions.

4. Determination of direction

· RFID tags will be used to determine the direction of the train's travel.

• There must be three sorts of movement directions: one for trains (forward or reverse), one for traffic (UP or DN), and one for movement direction (Nominal or Reverse).

• The direction would be determined when the Loco/Train passes two RFID tags with Absolute position (except Adjustment tag).

• If the Absolute location value increases, it is considered as Nominal direction. If Absolute position is decrementing, it is considered Reverse direction.

• The movement direction of the train and the TIN must be utilized to evaluate if two trains are approaching, following each other, or moving away from each other.

• The Stationary TCAS unit shall use the direction of movement of the Loco/Train to locate the approaching signal of the Loco/Train.

5. Train Length Assignment

- Every stationary TCAS unit shall monitor the state of the track section designated for train length measurement. (Only applies to Station TCAS units.)
- Loco TCAS unit must compute its train length based on the time of occupation and clear status of these track sections provided by Stationary TCAS unit.
- At each station, a two-track circuit (say, AT & BT in sequence in the traffic direction of train movement) at the entry to the block section shall be indicated for train length measurement. The track circuits defined must be such that all trains entering a block section pass over them.
- The status of these track circuits shall be taken as an input to the stationary unit.
- Stationary unit shall communicate the time offset from frame cycle reference for 'BT occupied' and 'AT cleared' to concerned Loco unit, which shall be used by Loco unit for precise location for train length calculation.
- In the event of overlapping territories, the train length measurement record should be passed on by taking over station.

Salient Features of KAVACH

- The Kavach anti-collision system operates on the concept of continuous update of Movement Authority through radio. The following are the salient attributes of Kavach:

- In the event that Loco Pilot fails to control the train's speed, Kavach applies brakes automatically.

- The line side Signal Aspects are replicated in cab, which is super useful at high speeds and in foggy conditions. Kavach is interfaced with current signal interlocking systems for this purpose.

- Kavach operates on the principle of continuous updating of Movement authority via radio communication, which is now in the UHF range.

- It is compatible with existing signaling interlocking systems, including relay-based interlocking.
- Kavach meets SIL-4 (Safety Integrity Level - 4), the highest level of safety certification.

- Kavach additionally contains non-signaling based collision prevention features that are non-SIL.

Operational modes in Loco TCAS

The TCAS loco equipment are capable of supervising the following operational modes:

S.no	Operation	Function
1.	Stand By (SB)	The Stand-By mode shall be default mode and shall not be possible to be selected by the loco pilot.
	Staff Responsible (SR)	The Staff Responsible mode allows the loco pilot to move the train under his own responsibility in TCAS territory.
	Limited Supervision (LS)	The Limited Supervision mode enables the train to be operated in areas where partial trackside information (Movement Authority/Section speed) is available for supervision of the train.
	Full Supervision (FS)	The Loco TCAS unit shall be in the Full Supervision mode when all train and track data including Movement Authority and Static Speed Profile up to Movement Authority or up to 3000m, whichever is less, which is required for a complete supervision of the train, is available and in case of new train formation, train has crossed at least one stop signal in OFF condition. Full Supervision mode cannot be selected by the loco pilot, but shall be entered automatically when all the necessary conditions are fulfilled. The Loco TCAS unit shall supervise train movements against a dynamic speed profile. The Loco TCAS unit shall display the train speed, the

		permitted speed, the target distance and the target speed to the loco pilot.
	Override (OV)	The Override mode enables the train to pass the signal at danger.
	On Sight (OS)	The On Sight mode enables the train to enter into a track section that could be already occupied by another train.
	Trip (TR)	When a Train in Full Supervision or Limited Supervision Mode passes a stop signal at ON or End of Authority + 30m, the loco TCAS unit shall enter into Trip Mode. The Loco TCAS unit shall perform the Standstill Supervision in Trip mode. The emergency brake shall be applied until the Train comes to halt. Operation of the train trip shall be indicated on the DMI. When the Train is stationary, the loco pilot shall be required to acknowledge the train trip condition. This acknowledgement will release the emergency brake.
	Post Trip (PT)	The Post Trip mode shall be entered immediately after the loco pilot acknowledges the trip mode. Loco TCAS unit shall supervise the train against a ceiling speed of Post Trip Mode (Default: 15 kmph) and shall exit the Post Trip Mode after crossing the next approaching signal at OFF
	Reverse (RV)	The Reverse mode allows the loco pilot to change the direction of movement of the train and drive from the same cab, i.e., the train orientation remains unchanged.
	Shunt (SH)	A TCAS equipped traction unit shall be capable of being moved in shunt mode. Shunt mode shall be selected by the loco pilot. It shall only be accepted when the train is at standstill
	System Failure (SF)	The Loco TCAS unit shall switch to the System Failure mode in case of a fault, which affects the functioning of Loco TCAS. The Loco TCAS unit shall permanently command the Emergency Brakes. The Loco Pilot shall isolate TCAS, which

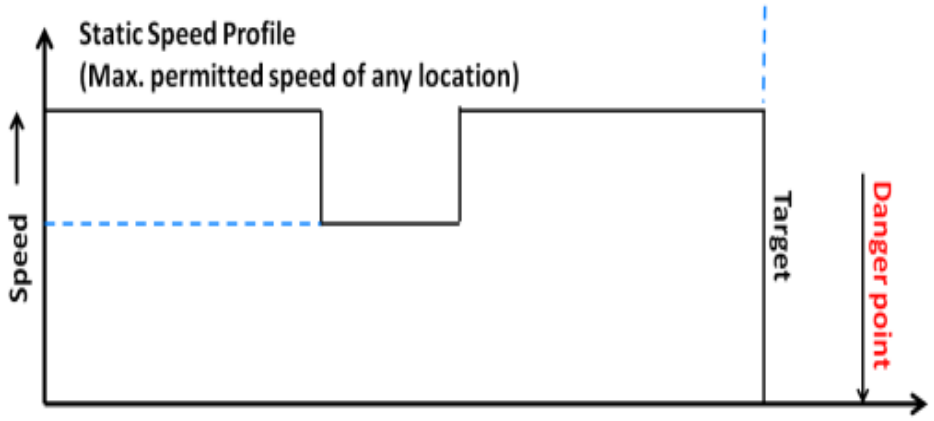
		means that Loco shall be no more under the control of Loco TCAS unit.
	Isolation (IS)	In Isolation mode, the Loco TCAS unit shall be physically isolated from the brakes. Loco TCAS Unit shall attempt to transmit an Onboard-to-Stationary Radio Packet at a periodicity of not less than 02 minute on encountering any tag (excluding LC Gate Tag) in one of the randomly selected access timeslots merely to indicate the Loco TCAS isolation mode to NMS through Stationary TCAS Unit

Speed profile layer

The Speed Profile Layer's purpose is to enable running time estimations, which involves 2 parts: track resistance and speed restrictions. Track resistance is determined by the gradient and curvature of the track, which can be stored in a graph or retrieved by a service, depending on the Physical Layer implementation. Speed restriction, on the other hand, is governed by two distinct limitations. The first limitation is due to physical constraints caused mostly by curvature; the second limitation is caused by train movement. This yields two profiles: a static and a dynamic speed profile.

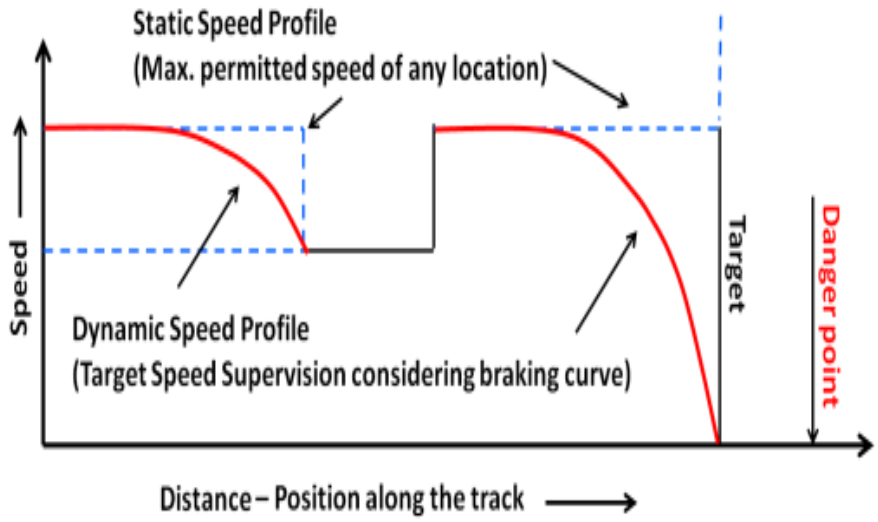
Static Speed Profile (SSP)-

The Static Speed Profile (SSP) defines the set speed restrictions for a section of track that is sent from trackside to train. The SSP addresses the maximum allowable speed at any given location. The static speed profile is a parameter that specifies the maximum permissible speed on the track depending on the physical parameters of the track (curves, restriction to pass a point). The SSP is one of the data that enables the train to manage supervision (Full Supervision, On Sight); in order to do so, the train must be familiar with the SSP throughout the Movement Authority.



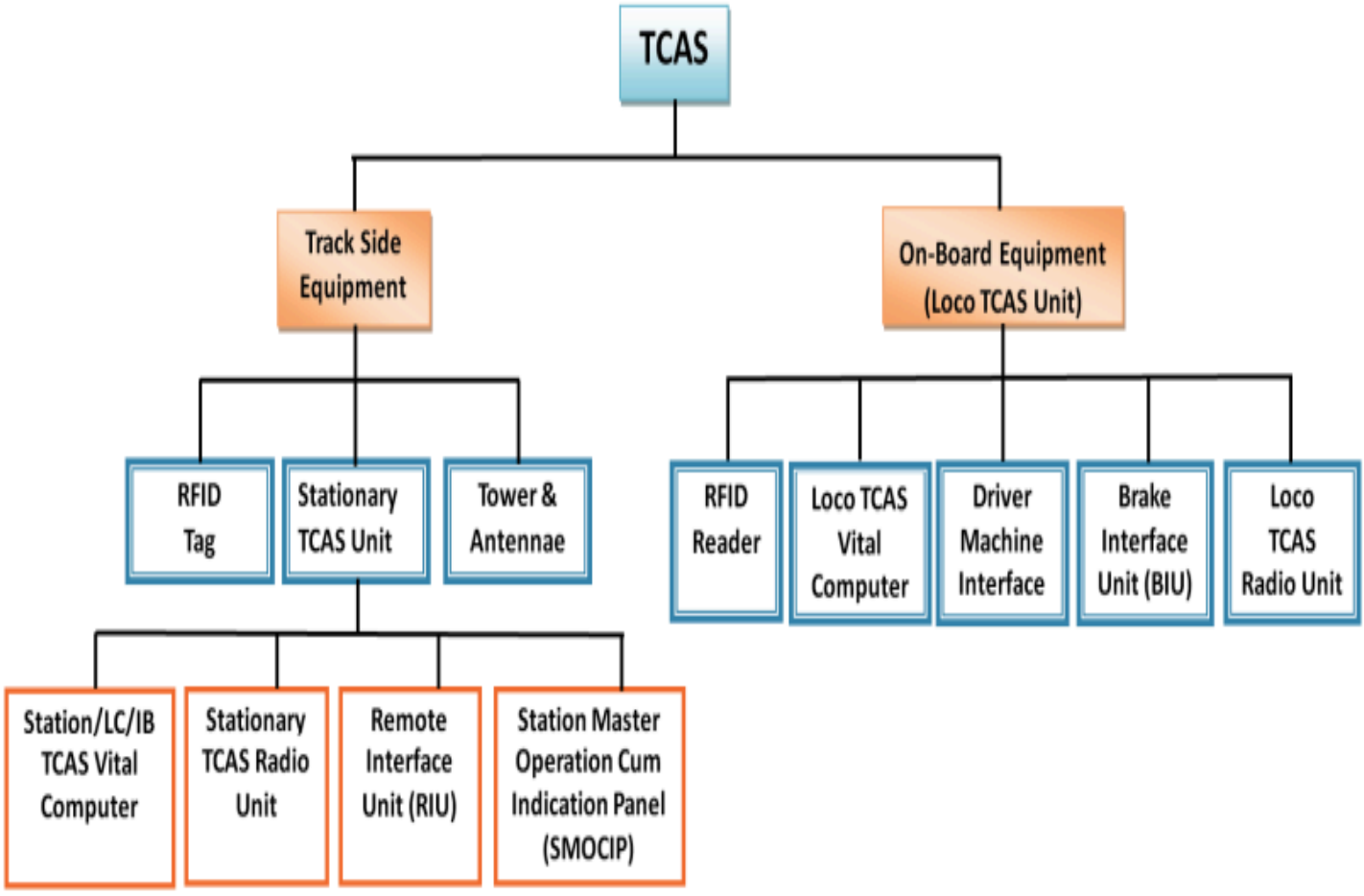
Dynamic speed Profile (DSP)-

The Dynamic Speed Profile is the speed-distance curve that a train must follow without breaching the static train speed profile until the movement authority ends. This curve is determined by the train's braking characteristics as well as the length of the train. The dynamic speed profile takes into account the train's possible acceleration or deceleration curve.



Dynamic Speed Profile (Distance- Speed graph) of a train

Flowchart of TCAS Sub-System



TCAS Key System Components



Trackside Sub-system

The Trackside subsystem shall be composed of

(i). RFID tag (ii). Stationary TCAS Unit (iii). Tower and Antennae

(A) RFID Tag

To the locomotive, RFID tags deliver site-specific static data. Apart from serving as location references, these also relieve the Radio Channels and send instantaneous information to the Loco Unit, such as crossing the signal, etc. RFID tags should be installed on track in the station section, point zones, near Signals & track in the block section to provide Trackside information to the Loco TCAS unit. RFID tags must be installed on sleepers between railways in accordance with Indian Railways guidelines. RFID tags must meet the following requirements:

• Suitable for reliable operation at train speeds of up to 200 KMPH (minimum).

• Operating frequency: 865-867 MHz

• Can be programmable with a minimum of 128 bits of user data (including CRC).

• Must be able to operate while submerged in water up to rail level.

· Under field operating conditions, the RFID reader antenna must be able to read RFID tags from a vertical distance of 700 mm from the bottom of the RFID reader antenna to the top of the rail level.



RFID Tag fixed on sleeper

(B)Stationary TCAS Unit

Stations must have a stationary TCAS unit to cover all trackside signals. It must also be provided at Intermediate Block Locations (IBS) and midsection interlocked

Level Crossing Gates where the station TCAS tower's radio signal coverage is inadequate. This will be interfaced with interlocking equipment to obtain real-time dynamic signalling information such as various signal aspects. It contains a database of static signaling-related information such as RFID tag location and details and speed restrictions. It receives real-time information about the locations, speeds, and other characteristics of different trains in its jurisdiction via UHF radio communication. Based on this information, it recognises any emergency situation and may order Loco to take action to stop it. Stationary TCAS Unit shall comprise of:

1. Station/LC/IB TCAS Vital Computer
2. Stationary TCAS Radio Unit
3. Remote Interface Unit
4. Station Master Operation cum Indication Panel (SMOCIP)



Station TCAS unit

On-board Sub-system (Loco TCAS Unit)

The On-board subsystem shall be comprised of:

1. Loco TCAS Vital Computer
2. RFID readers consisting of two RFID Reader Antenna in hot standby
3. Loco TCAS Radio Unit consisting of two Radio Modems in hot standby with separate cables and antennae for each radio or LTE unit (XX Nos) as prescribed by the purchaser.
4. Two Driver Machine Interface (DMI) for each locomotive or one DMI for each Driving motor coach of EMU/DMU/MEMU/DEMU etc.
5. Brake Interface Unit (BIU), where required (vi). The system shall be interfaced with LTE BTM Reader, for TPWS



Loco TCAS unit