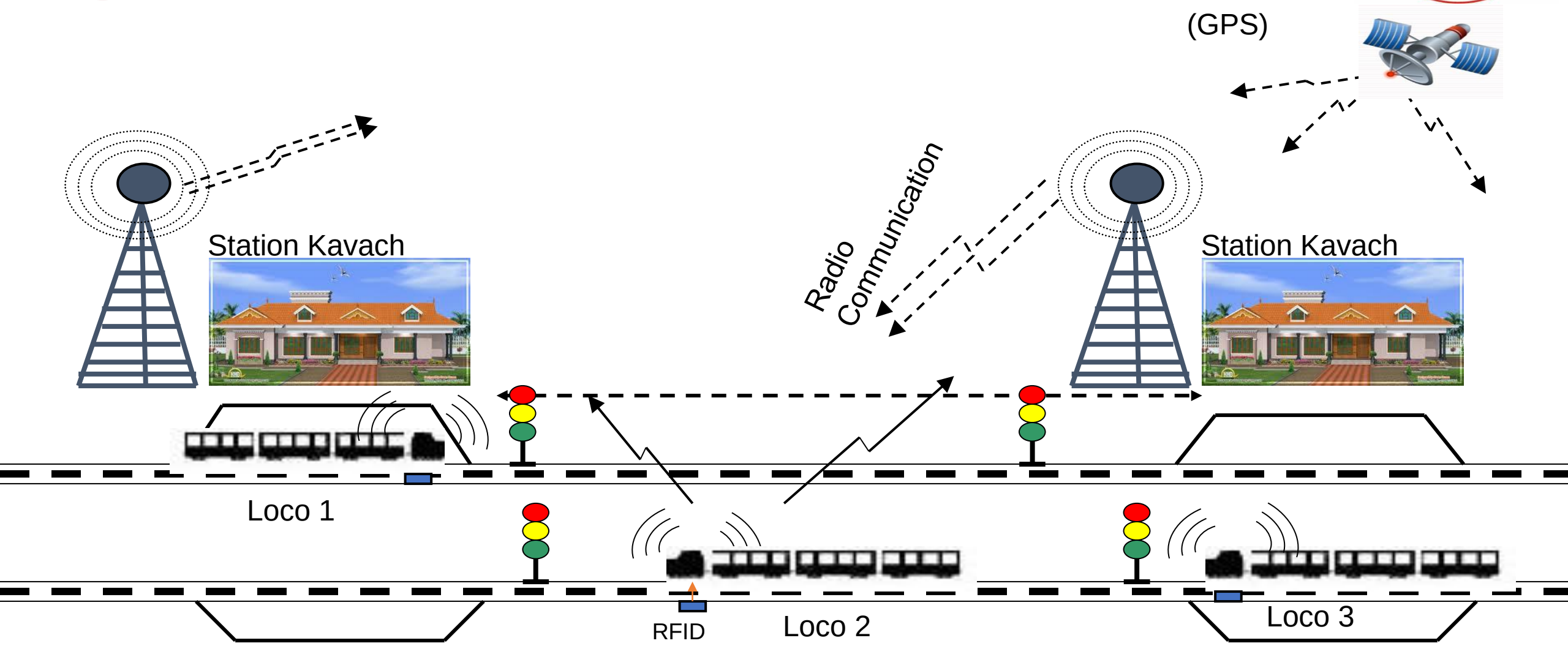
A BRIEF
ON
KAVACH (IRATP)

RDSO SPECIFICATION

Latest RDSO Spec: RDSO/SPN/196/2020Version 4.0

(Old RDSO Spec: RDSO/SPN/196/2012 Version 3.2)

KAVACH - Deployment plan



What is KAVACH ?

- **KAVACH / Train Collision Avoidance System (TCAS)** is an indigenously developed **Automatic Train Protection (ATP)** System

- Provides protection to Trains against **Signal Passing at Danger (SPAD)**, **excessive speed and collisions**.

- KAVACH provides continuous update of **Movement Authority** (distance up to which the train is permitted to travel without danger).

- The communication between Stationary KAVACH and Loco KAVACH units shall be **Safety Integrity Level-4 (SIL-4)** certified

Salient Features of KAVACH

- Prevention of SPAD
- Cab-Signaling, Loop Line Speed Control
- Prevention of Over speed: Section Speed, Train Speed, Permanent Speed Restriction (PSR)
- Protection of Roll back and Reverse movements
- Prevention of Side-collision in block section
- Prevention of Head-on & Rear end collisions
- LC Gate Automatic Warning **Save Our Souls (SOS)** Messages
- Computation of Train Length
- Shunting Limits Validation
- Centralized live monitoring of Train movements in Networking Management System (NMS).

System Overview

- The Trackside sub-system of KAVACH consists of RFID tags fitted on track in station section / block section for giving Trackside information to Loco KAVACH unit installed in the locomotive.

- Portions of track including berthing tracks, point and block sections are assigned unique IDs called Track Identification Number (TIN).

- The system also consists of Stationary KAVACH unit installed at Station with radio tower to communicate with locomotives in the jurisdiction of Stationary KAVACH which commence on approach of its first Signal.

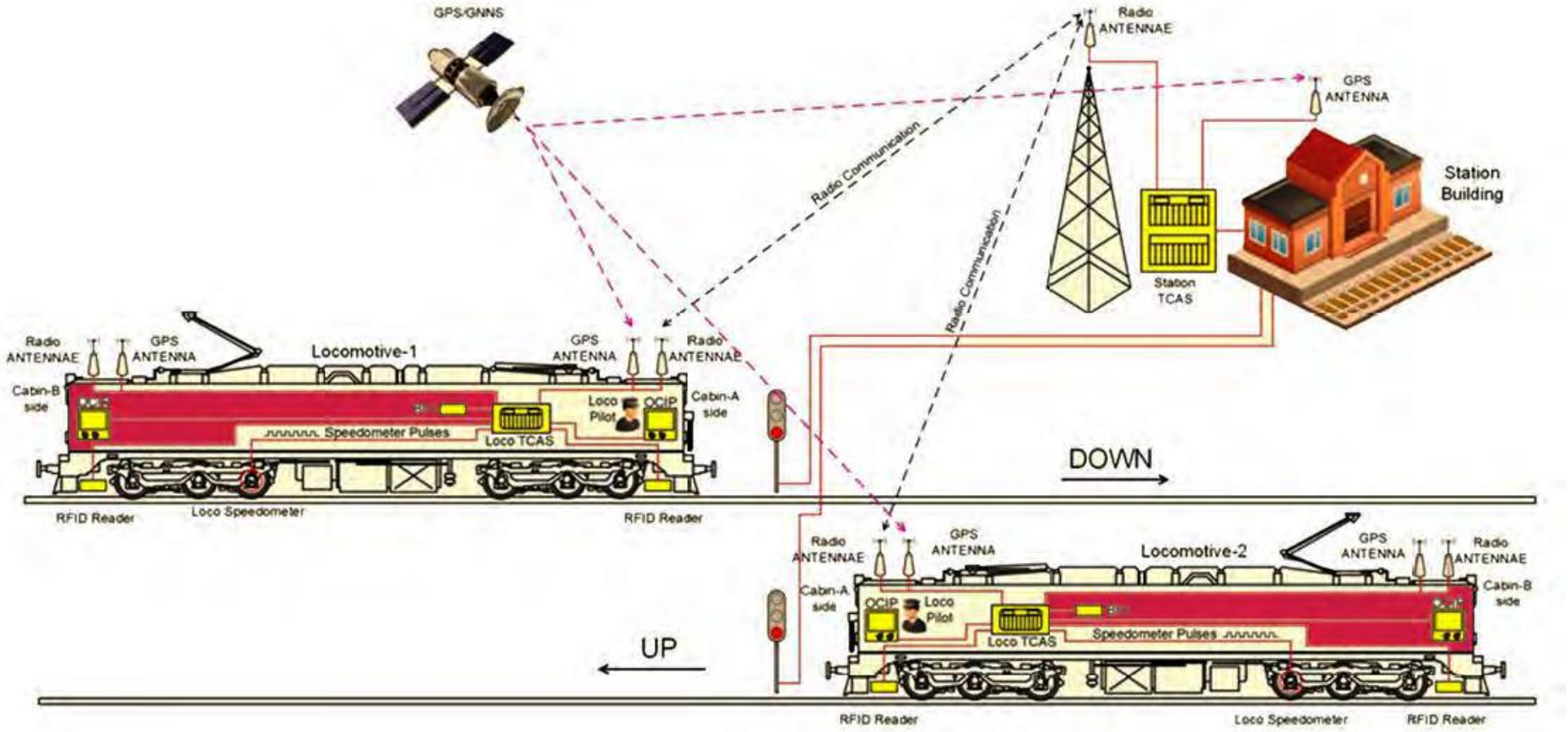
System Overview (contd..)

- Stationary KAVACH is interfaced with station interlocking to acquire real-time dynamic information related with signaling such as various signal aspects.

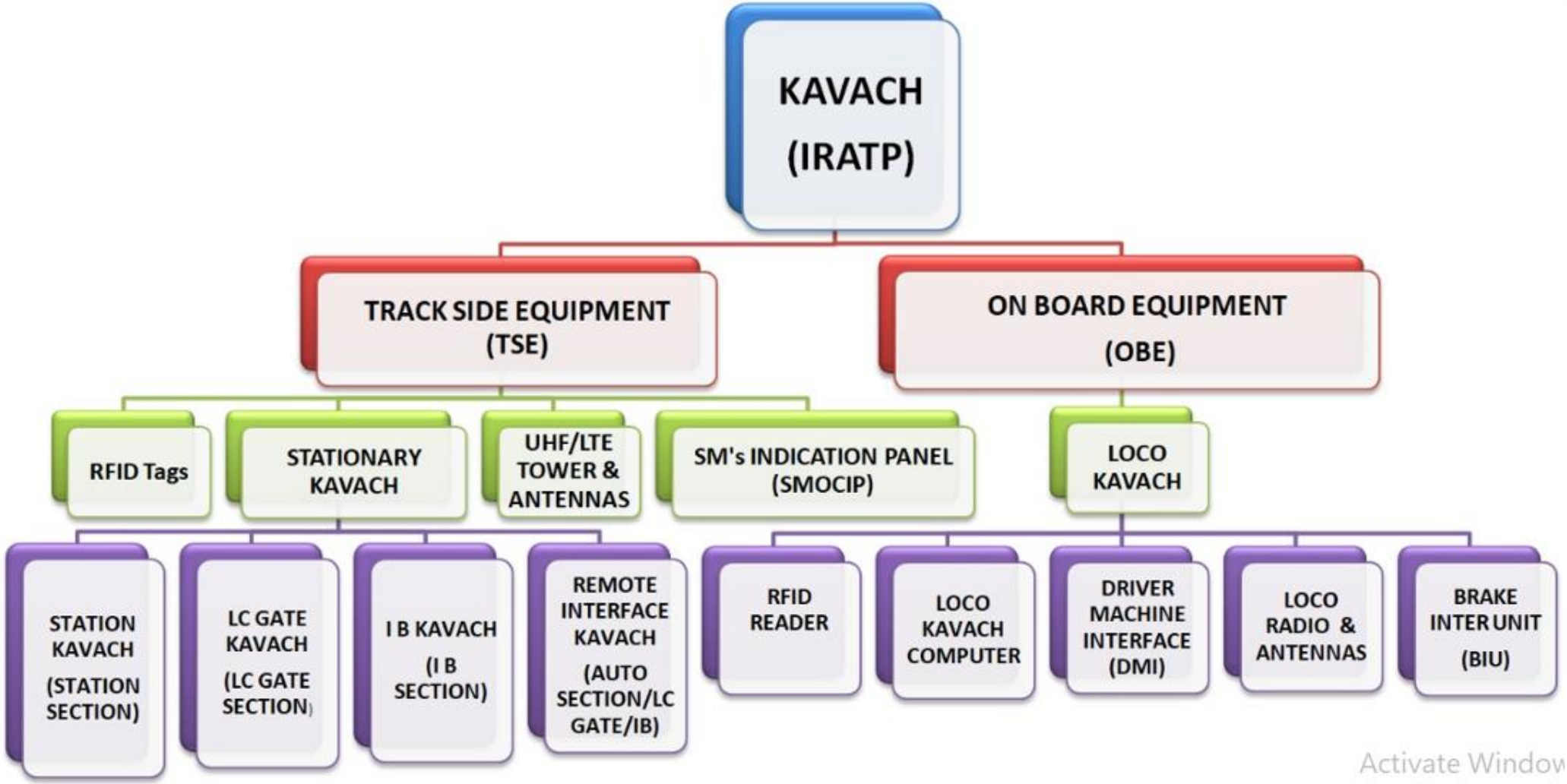
- Route information of all the signals monitored by a specific stationary KAVACH unit and is configured on the basis of KAVACH Control Table (excluding shunt signals and overlaps).

- Stationary KAVACH unit gets real-time information regarding Locations, Speed etc of various trains in its jurisdiction through UHF Radio Communication.

Kavach General Architecture



System Architecture



System Key components

LOCO

Loco TCAS

Loco Pilot – OCIP

Brake Interface Unit

RFID Reader

STATION

Station TCAS

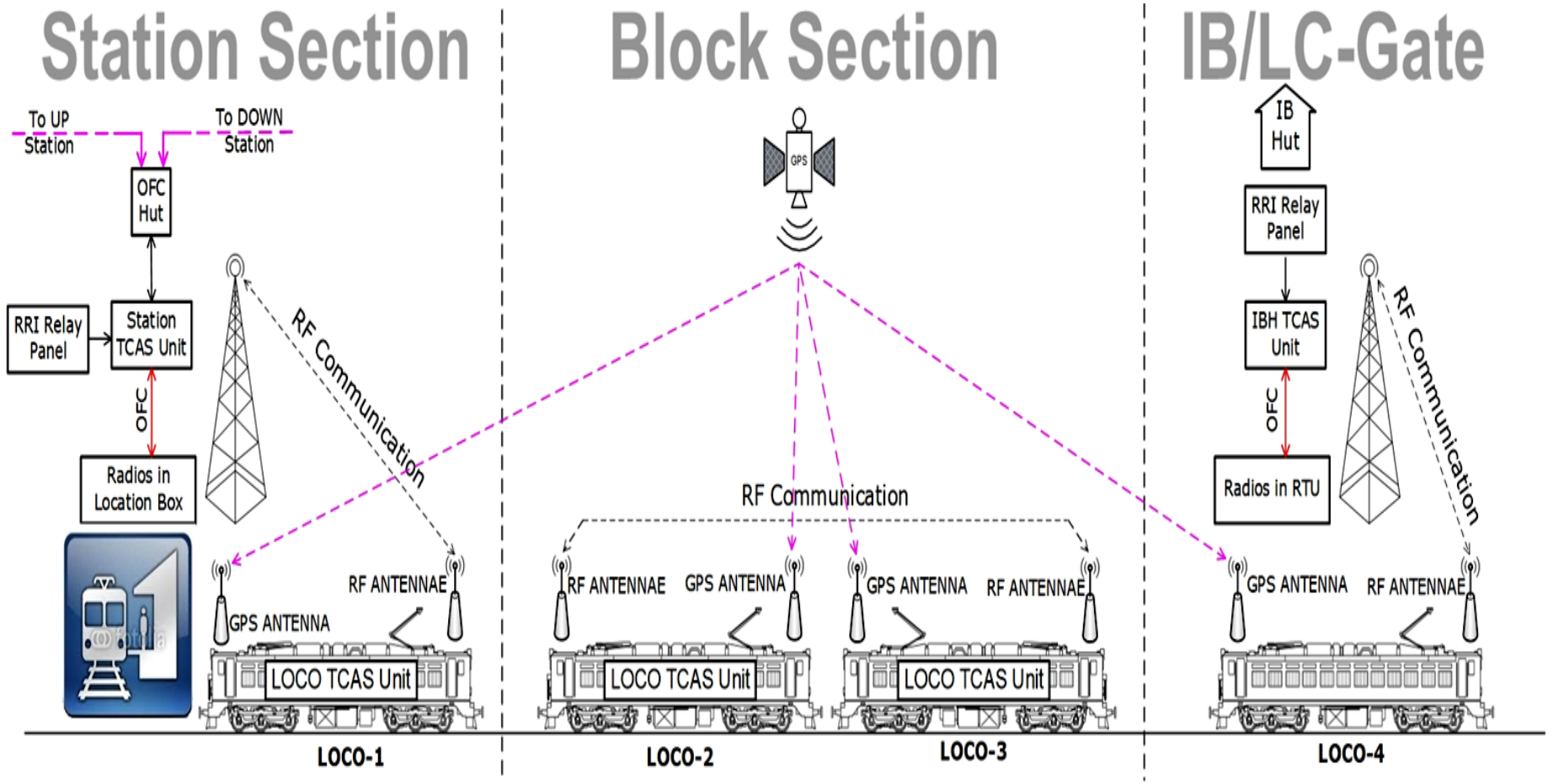
Radio Tower

Station Manager – OCIP

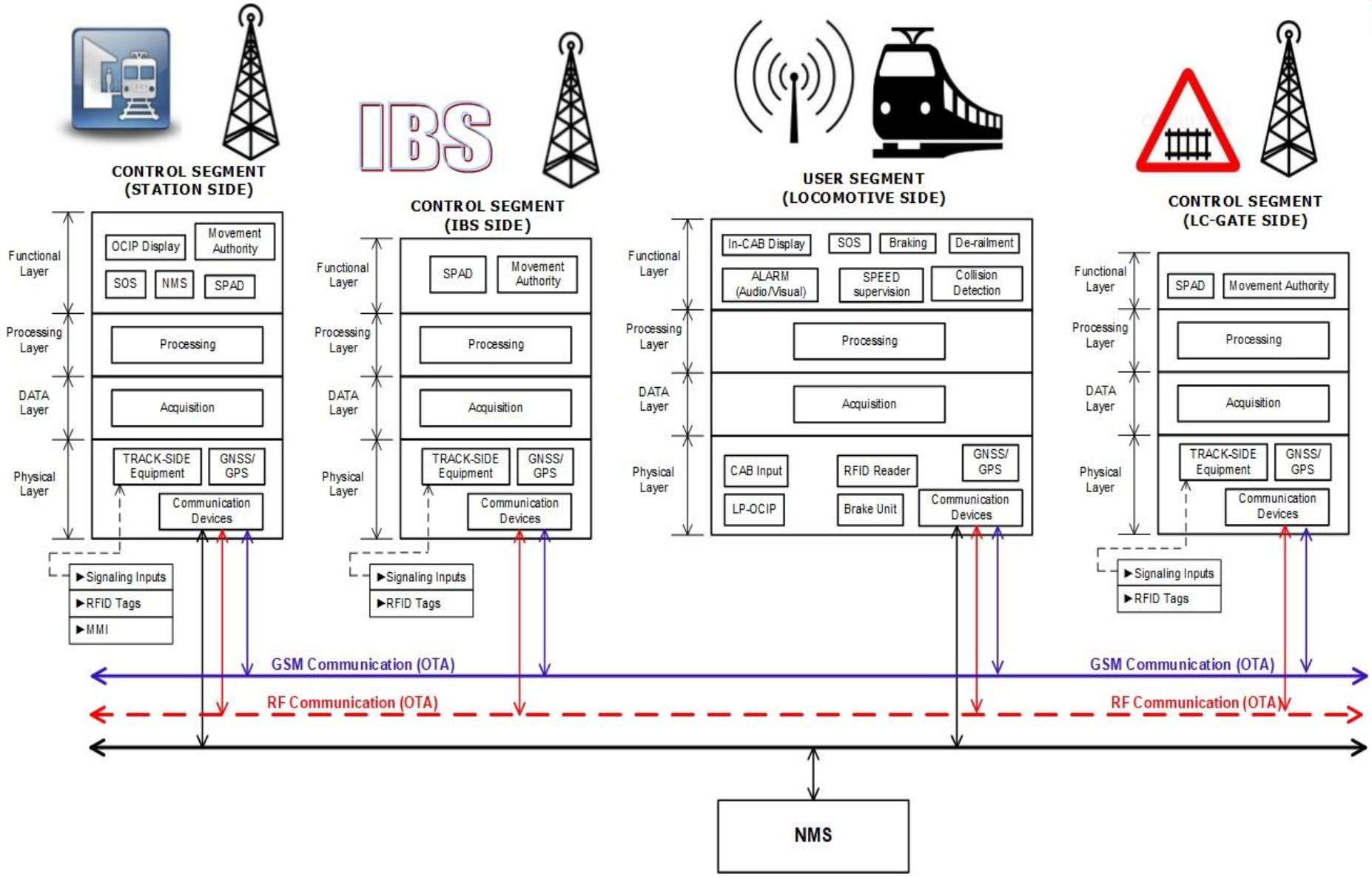
TRACK SIDE

On Track RFIDs

Kavach Applications



KAVACH Process flow



Systems of Kavach

The Kavach broadly comprises of following components:

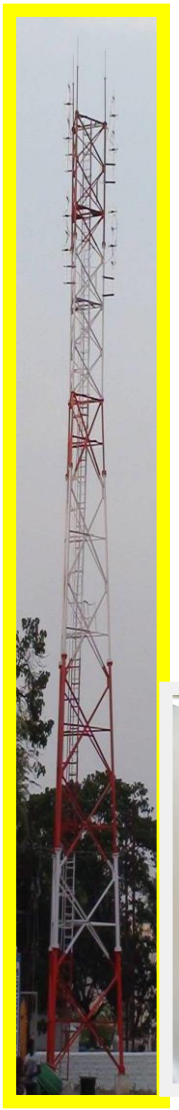
Track side Sub-systems

The Trackside subsystem shall be composed of

- RFID tag
- Stationary KAVACH Unit
- Tower and Antennae

System Components

TOWER



KAVACH UNIT

VITAL RELAYS

RADIO UNIT

SM-OCIP

Remote Interface Unit (RIU)

- A Separate *Stationary KAVACH unit i*s provided at Mid–Section interlocked Level Crossing Gate and Intermediate Block Signaling (IBS) locations if they do not come within the coverage of station radio tower.

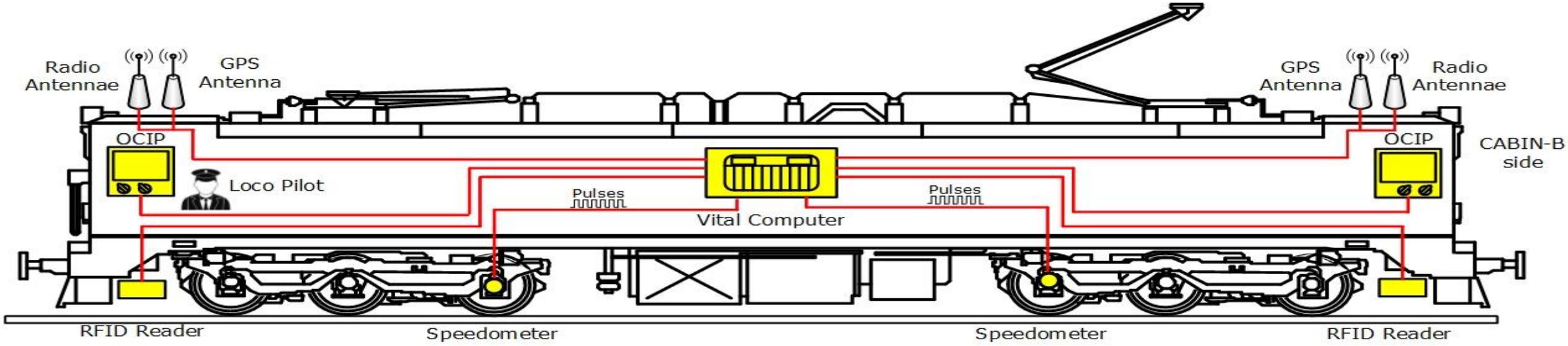
- Remote Interface Unit (RIU) shall be used where remote signaling functions are required to be fetched to a nearby Stationary KAVACH unit for example from end cabins/ distributed interlocking or LC gate/IB coming within the radio coverage of station tower

KAVACH – RFID Tags

Types of RFID Tags

1	Normal Tag	The maximum distance between the two normal tags. shall not be more than 1000m. Each Normal tag shall be linked to next two normal tags in both the directions
2	Signal Foot Tag	To indicate the Signal Foot to the Approaching train If loco crosses this without MA, loco enters into Trip mode
3	Signal Approach Tag	Signal approach tags shall be provided before the approach of (typically 150 ~ 250m) every signal post to correct the odometry error
4	TIN Discrimination Tag	shall be used to indicate change in the TIN of track section. Normally it will be placed at turnouts.
5	LC Gate Tag	shall be provided at both sides of LC gate at around 600 to 850 Mts
6	Adjustment / junction Tag	Shall be used to adjust the absolute location in the block section. Junction tag shall be provided, at the junction stations to correct the absolute location. Junction tag data shall not be used to determine the train direction movement such as Nominal or Reverse
7	Exit Tags	shall be provided at TCAS territory exit point

KAVACH Installation in Locomotive



On-Board Sub-Systems

The On-board subsystem shall be comprised

- Loco KAVACH Vital Computer
- RFID Reader
- Loco KAVACH Radio Unit with antennas and other communications
- Driver Machine Interface(DMI)
- Brake Interface Unit (BIU)

Overall Functionality Mechanism

Requirement	Mechanism in KAVACH
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 Signalling Information by stationary KAVACH of station/IB/LC gate vital computer.	Interfacing to station interlocking (PI/RRI/EI)
Transfer of Signalling related information from Station KAVACH to Train	Radio Communication between Stationary unit & Train units through dynamic TDMA on a specific frequency pair in station area. Stationary units are allocated time slots according to Topography and their size. Mobile units i.e. Trains are as signed slots dynamically. This provides efficient utilization of channels.
Loco to Loco message broadcast	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.

Functionality Mechanism (contd..)

Requirement	Mechanism in KAVACH
Prevention of over speed and SPAD	By reducing the movement authority based on the aspect of approaching signal.
Prevention of collisions between two trains	Through conflict between signal aspect, point position, berthing track section, signal aspect sequence and TIN in station area and through TIN conflict in block section.
Centralized monitoring of KAVACH equipped trains and stations	Through Network Monitoring System (NMS)
Security of radio communication between Stationary KAVACH and Loco KAVACH	Using GSM/GPRS communication techniques through a Key Management System (KMS)
Real Time Clock (RTC) synchronization	Through Global Positioning system (GPS)/ Global Navigation Satellite System (GNSS).

Kavach Functional Description

- Station Kavach collects the current status of all the field inputs like signal aspects, points, track circuits and berthing tracks.
- Based on the status of these inputs, Station Kavach calculates the Movement Authority for the Loco(s) considering their absolute position and the routes that are set for those travelling in the Station vicinity.
- It also obtains the current signal aspect and next signal aspect for each Loco considering the current status of all the above inputs.
- GPS is the time reference for Loco and Station Kavach systems to perform Radio Communication.

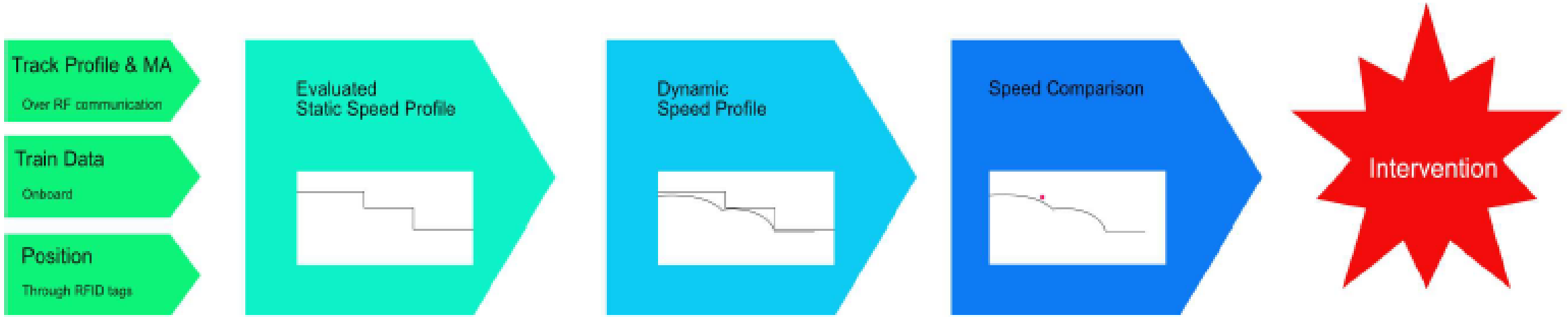
Kavach Functional Description Cntd…

- Loco Kavach reads the Location programmed in the RFID tags, which are mounted over the track and establishes its direction of movement (Nominal/Reverse).
- Loco Kavach receives the data transmitted by the Station Kavach and travels in accordance with the received Movement Authority.
- Loco Kavach frames the information containing its operating mode, absolute position, last RFID tag, movement direction, Track Identification Number (TIN) as a single communication packet and send it to the Station Kavach.
- In the event of emergency situations, SOS messages will be generated and Loco Kavach applies emergency brake.

Static Speed Profile

- **Static speed profile:** The Static Speed Profile (SSP) is a description of the fixed speed restrictions for a part of track sent from trackside to train.
- PSR information is communicated from the Stationary Kavach system.
- In addition to PSR information, Section Gradient and LC gate location is communicated to the trains.
- Change in the PSR location, can be modified by changing the Station Application Data.
- Temporary Speed Restrictions also can be implemented by adding into the station application data when required.

TCAS – Operational Principle



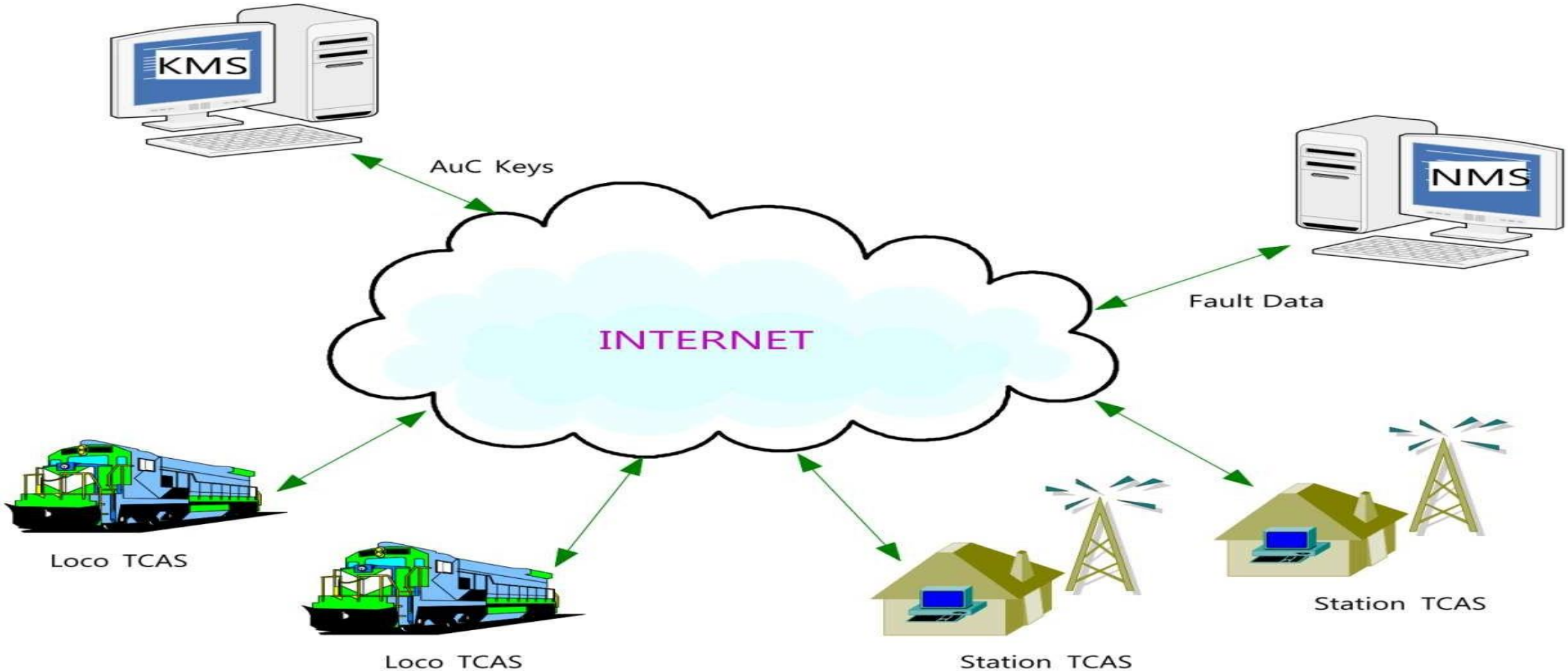
Communication Arrangements

- In the KAVACH, System Radio Communication shall use cryptographic techniques to transfer messages between Loco KAVACH and Stationary KAVACH units.
- For secured communication, Authentication keys are received by Stationary KAVACH and Loco KAVACH using Global system for Mobile Communications (GSM)/ General Packet Radio Service (GPRS) communication through a Key Management System (KMS).
- Time Clocks (RTC) of all the KAVACH systems are synchronized with Global Positioning system (GPS)/ Global Navigation Satellite System (GNSS).

Radio Communication

- Communication packets shall be of a maximum size of 1024 bits.
- Kavach sub-system shall split the packet into multiple packets if it exceeds maximum communication packet size (1024 bits).
- The transmission Over-The-Air from Radio shall be controlled by Kavach Subsystems using Request To Send signal in the RS232.
- Kavach sub-system may transmit multiple Communication packets in a single transmission burst.
- Kavach sub-system shall transfer all the data for a single transmission burst to the Radio modem at least 20milli second before commencement of Over-The-Air.

KMS & NMS PROCESS



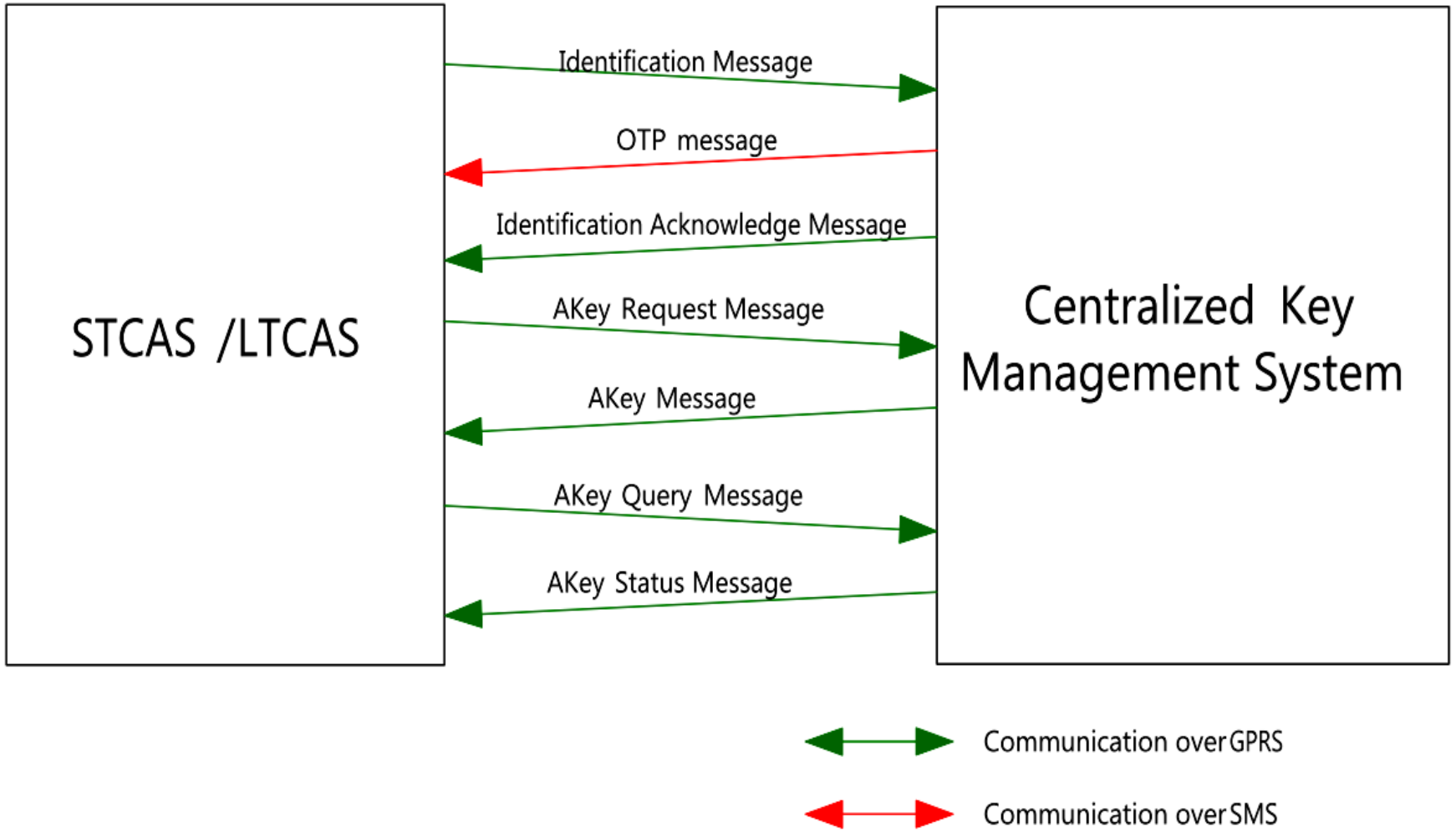
Radio Communication - Packets

Radio Packet	Function
Access Request Packet (Loco)	• To request time slot • To establish secure radio communication
Access Authority Packet (Station)	• Allocates time slot • Loco verifies secure communication status
Loco Regular Packet (Loco)	• Transmitted in allotted time slot • To request MA and Track Data • Transmitted only when secure radio communication is successful
Signal Information Packet (Station)	• Transmitted only when secure radio communication is successful • Transmits MA, Signal Aspect and Track Data to loco
Emergency Status Packet (Station)	• SOS message
Static Speed Profile Packet (Station)	• Track Data (Gradient Info, LC gate info and Speed profile)

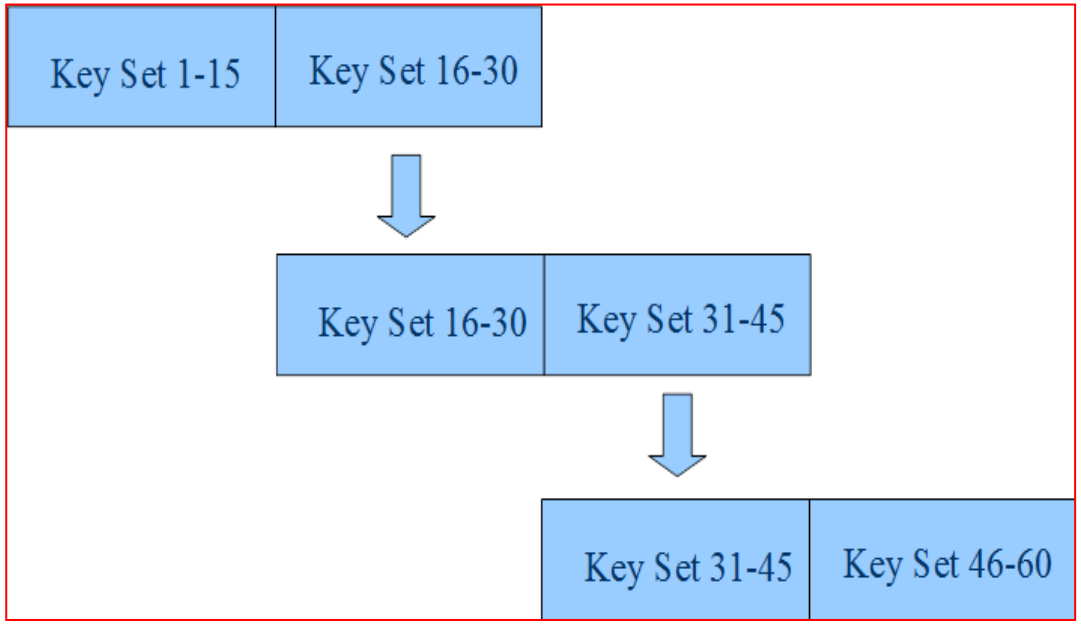
Key Management System (KMS)

- The *onboard Loco KAVACH* unit installed in the locomotive determines the location of train by reading pre-programmed *RFID Tag data* with the help of *RFID reader.*
- By using the cryptographic technique malicious attacks will be eliminated. Only Authenticated Systems communicate *with each other* to ensure the *safety of the* system.
- Key Management System (KMS) is developed to check for authentication and distribution of secret keys.

Authenticated keys transmission



Key Generation and Distribution



- After expiry of 15 keys, new 15 keys are randomly generated and appended to the last 15 keys of existing key set.
- 30 keys limit for 120 days.

Kavach Functions – SPAD Prevention

- Kavach warns the loco pilot to stop the train if it senses the potential occurrence of a SPAD event, through an audio-visual alert.
- If the loco pilot does not attend to this alert, Kavach automatically stops the train ahead of the STOP signal.
- Kavach braking logic determines the appropriate braking distance and deceleration effort required to stop the train before the STOP signal, based on train configuration and running speed.
- The train can be re-started in the normal way, once the STOP signal is cleared.

Head on & Rear end Collision

Capable of detecting head on collisions, rear end collisions in all possible scenarios based on

- *track identification, speed of the trains*
- *train location,*
- *train length,*
- *train direction movement*

- In case of head on collision situation, Loco Kavach units of both the trains automatically applies the brakes
- In case of rear end collision situation, Loco unit of only rear train automatically applies the brakes
- In Station sections, Stationary Kavach prevents train collisions with the help of SPAD and TIN conflict through Loco specific SOS

Kavach Functions – In-cab Signaling

- Kavach displays signal aspects on its DMI.
- This allows the loco pilot to run the train,

  even with severely reduced visibility.
- Continuous update and display of movement authority on the DMI allows the loco pilot to run the train with confidence in such reduced visibility areas.

Kavach– DMI Screen

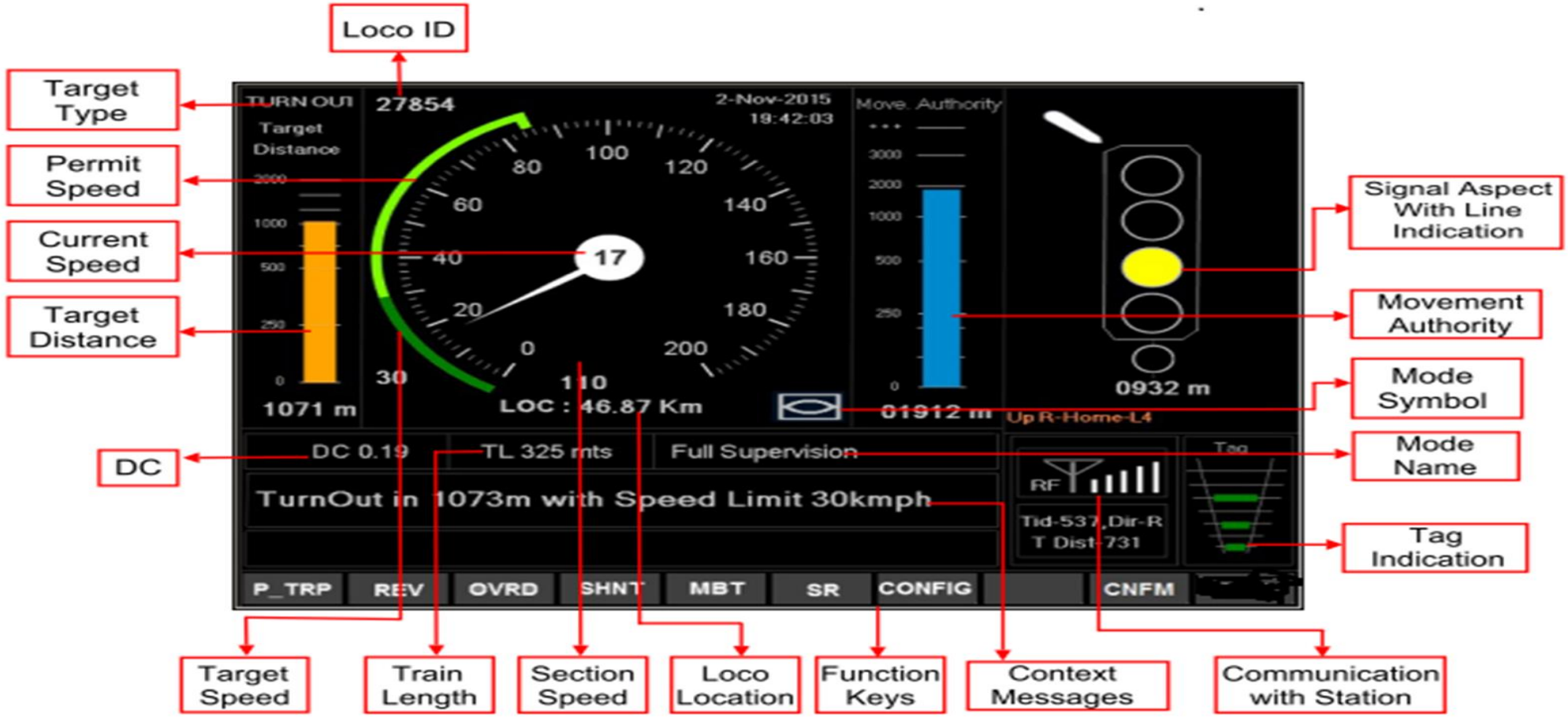
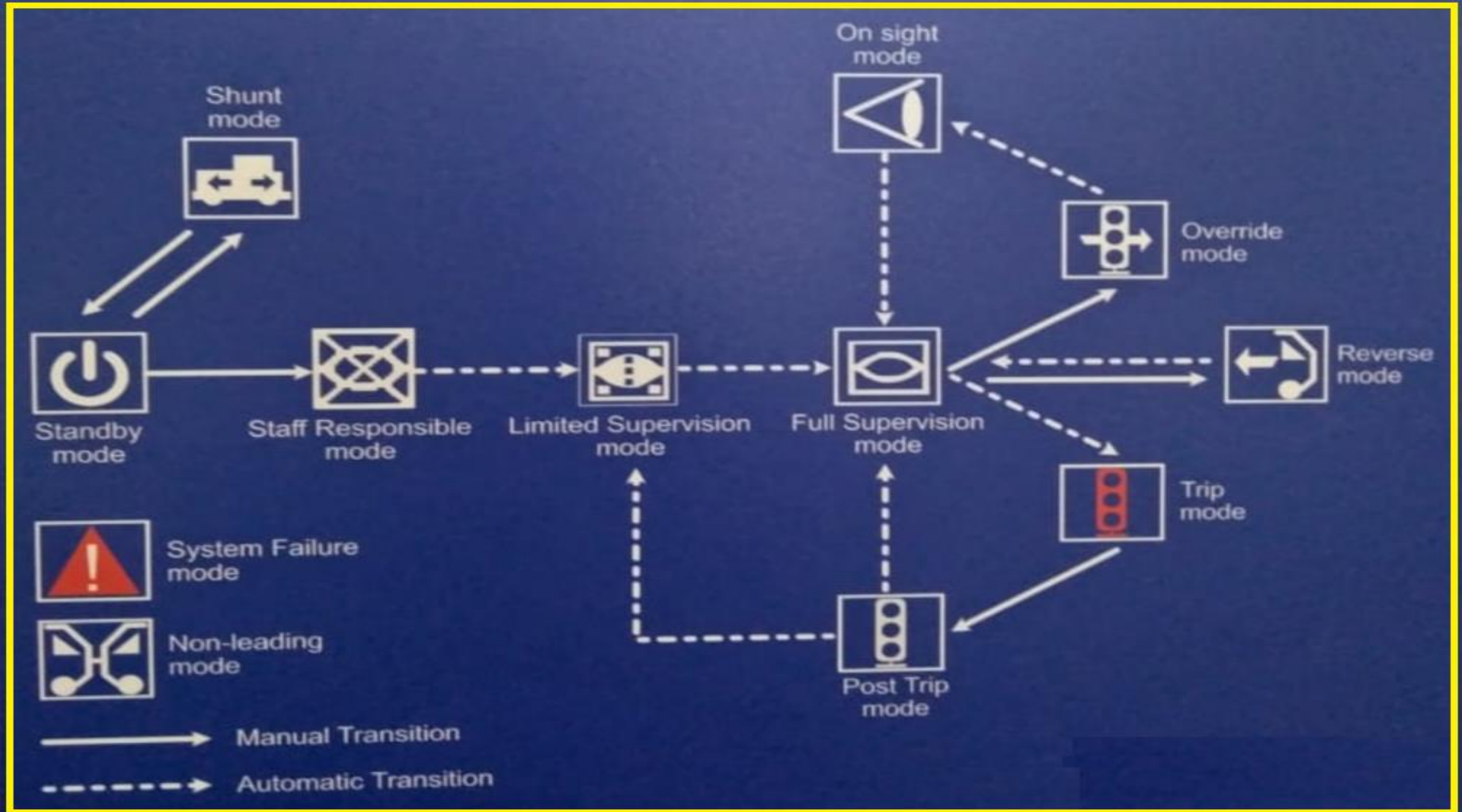


Fig 2.2

Modes of Operation

1		Stand by Mode
2		Staff Responsible Mode
3		Full Supervision Mode
4		Limited Supervision Mode
5		Override Mode
6		On-Sight Mode
7		Trip Mode
8		Post Trip Mode
9		Reverse Mode (to move in reverse)
10		Shunting Mode
11		Non leading Mode
12		System Failure Mode
13		Isolation Mode


On sight mode
Shunt mode
Override mode
Reverse mode
Standby mode
Staff Responsible mode
Limited Supervision mode
Full Supervision mode
Trip mode
System Failure mode
Non-leading mode
Post Trip mode
Manual Transition
Automatic Transition

Guide lines for KAVACH Control Table

Following guidelines shall be followed while preparing KAVACH Control table:

- KAVACH control tables shall be based on the SIP of the station as well as approved RFID tag-TIN layout for the Station/IB/LC.
- However, overlap points shall not be proven in KAVACH control table.
- Shunt signals shall not be a part KAVACH control tables.
- However, station shunt limits shall be specified in the Stationary KAVACH application data.

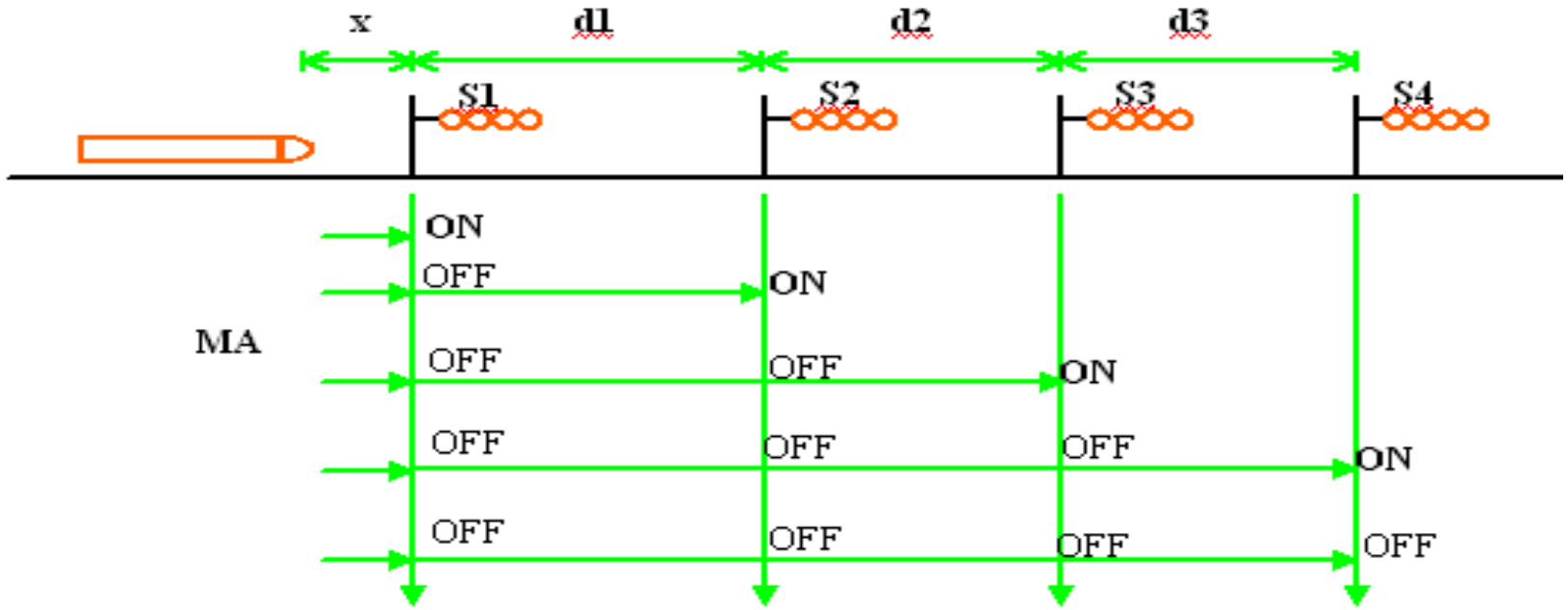
Guide lines for KAVACH Control Table (contd..)

- KAVACH control table shall include all signals which will be monitored by a specific stationary KAVACH unit.
- In case of permissive signals, where the inputs for signal indications are available, the ECR shall be used for the purpose of displaying signal aspect. However, movement authority shall be decided based on the signal aspect of the approaching Stop Signal.
- In case of permissive signals, where the inputs for signal indications are not available, the signal aspect and movement authority shall be derived based on the signal aspect of approaching stop signal.

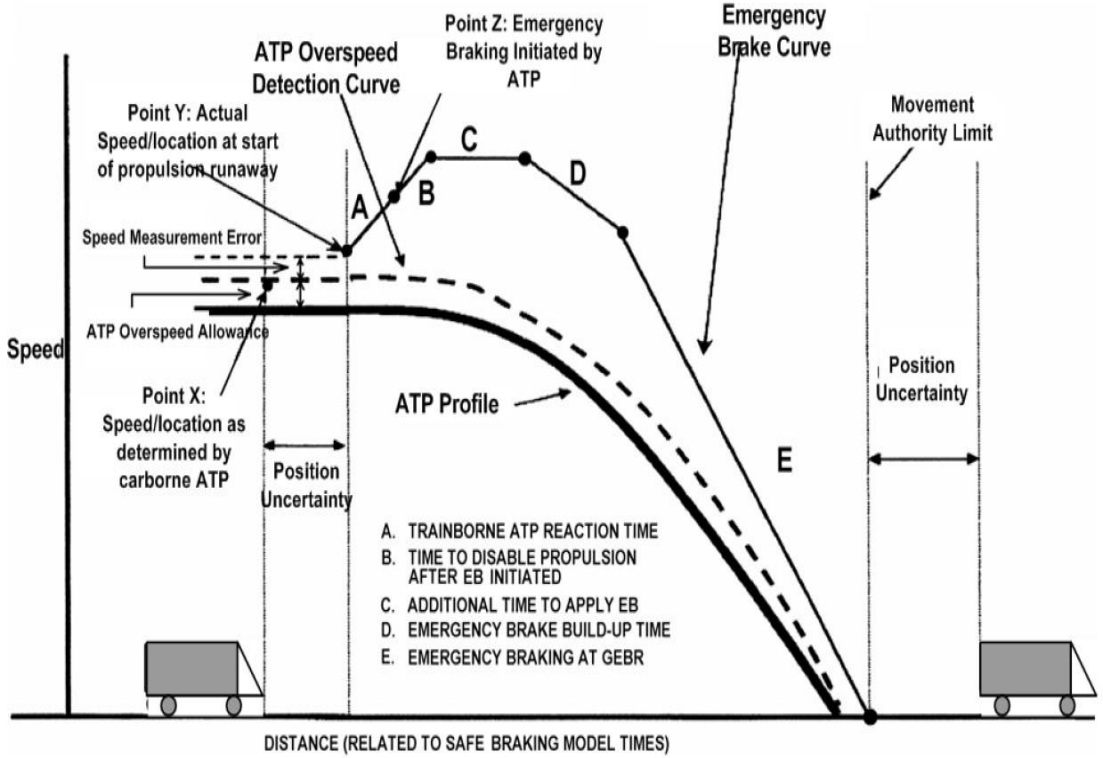
Movement Authority

Movement Authority: The distance up to which the train is permitted to travel safely.

End of Authority (EOA): Location up to which the train is permitted to proceed and where target speed is zero



Kavach - Speed Supervision & Safe braking



Speed Supervision

- Loop Line Speed
- Section/ Line Speed
- Max Train Speed
- Permanent Speed Restrictions (PSR)
- Speed related to loco modes
- Temporary Speed Restrictions(TSR)

Manual SOS

A UNIQUE feature even when a train is not protected by a signal

- Loco as well as Stationary TCAS unit have the provision of generating and canceling of SoS message by pressing SoS and Common buttons together
- The Loco TCAS units of all the trains/ Locos within 3000 m radius from Location of SoS originating source (as well as self-train) apply brakes to bring the train/
- locomotive to standstill
- After standstill, train speed is supervised to be within 30 kmph (configurable) till the train passes the originating Location of “SoS” message
- The normal speed would be restored only when any one of the following conditions are met,
  - SoS message is cancelled by the source
  - Train is moved away to more than 1500 m from the source
  - No SoS message for more than 3 minutes

Limitations of Kavach

- Kavach network cannot protect the train when :
  - Other Train is a NON-Kavach Train
  - ‘Adequate’ braking distance at that speed is not available when a ‘dangerous’ collision-like situation arises suddenly. However, severity of the collision would be reduced as a function of the reaction time.
  - Train derails and its wagons/coaches dash with another Train, already on ‘adjacent’ track
  - ‘Failure’ of brake power of the Locomotive/train

THANK YOU