

# **Railway Safety Audio Alert System (Camera-Based Detection of Obstacles and Signal Aspects)**

DRAFT Functional Requirement Specification (FRS)

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## 1. Introduction

Train drivers capabilities to detect obstacles and recognize railway signals are inherently limited due to human factors. Additionally, train drivers may become tired or distracted, which may result in missing signals or failing to detect obstacles. Modern technologies based on sensors, computers, and artificial intelligence enable the detection of obstacles and recognition of signals ahead of train drivers. The implementation of such technologies on locomotives will significantly improve railway traffic safety.

This document defines the functional and technical requirements for Railway Safety Audio Alert System - Camera-Based Detection of Obstacles and Signal Aspects. This document covers the basic features and operational requirements of the system. The usage of this document shall be limited to POC only.

## 2. Objectives and Scope

This document specifies the functional requirements for Railway Safety Audio Alert System - Camera-Based Detection of Obstacles and Signal Aspects (RSAAS or System) for Indian Railways.

This document has been prepared to define the requirements for the development of the System, which shall be capable of warning the Locomotive Driver about obstacles and infringing objects (as specified in this document) from a specified distances, in order to prevent collisions or mitigate their consequences.

## 3. Terminology / Abbreviations

- a) RSAAS — Railway Safety Audio Alert System - Camera-Based Detection of Obstacles and Signal Aspects
- b) IR — Indian Railway
- c) CRIS — Centre for Railway Information Systems
- d) NETD — Noise Equivalent Temperature Difference
- e) VIS — Visual Inertial System
- f) MTBF — Mean Time Between Failures
- g) BOM — Bill Of Materials
- h)

## 4. Scope of Supply

4.1. The proposed RSAAS for one loco shall contain following major components which are within the scope of supply of the vendor:

4.1.1. Sensor Module - 2 Sets (One set mounted at either end of the Loco).  
Each Sensor Module shall include 3 Optical Cameras and 1 Thermal

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Imaging Camera as detailed in Annexure- 3 (the sensor suite composition may be augmented by the Vendor).

- 4.1.2. Computation Module (may be integrated with other modules). It must be capable to meet all functional requirements as per section 5 and computation unit configuration as per Annexure-4.
- 4.1.3. Audio Alert Module - 2 units (One module installed in each cab of the Loco).
- 4.1.4. Display Module (optional, at supplier's discretion; may be combined with the Audio Alert Module).
- 4.1.5. Navigation Module (may be integrated with other modules).
- 4.1.6. 5G/LTE modem (optional, at supplier's discretion; may be integrated with other modules).
- 4.1.7. Required cables and interfacing equipment.
- 4.1.8. Hardware for mounting and cabling.
- 4.1.9. DC-DC Converter, as applicable to the type of locomotive (Input supply 110V for Electric Loco or 72 V for Diesel Loco).

## 5. Functional requirements

- 5.1. The system shall pre-warn the locomotive driver, well in advance, about any obstacle and/or aspect of signal (in accordance with the requirements specified in the Section 5) so as to give him/her an audio warning for each console (two consoles in each locomotive) enabling him/her to timely apply brakes so as to stop the train well short of the obstacle and/or to timely control the train as per the aspect of the signal.
- 5.2. Each working side of the locomotive will have one set of equipment consisting of all the necessary cameras/antennas/sensors for monitoring the track ahead in the direction of motion.
- 5.3. The system shall detect the following types of objects:
  - 5.3.1. Humans
    - 5.3.1.1. Humans of approximate size not less than 1.7 m (height) x 0.4 m (width) shall be detected at a distance of not less than 1000 m.
    - 5.3.1.2. For humans with lower size the range of detection shall be the function of object height according to the next equation:  

$$range(h) = 1000 * \frac{h}{1.7}, \text{ if } 0.7 \leq h \leq 1.7, \text{ where } h - \text{height of object (minimum object height for detection: 0.7 m).}$$
    - 5.3.1.3. Bikes and motorbikes with a rider of approximate size not less than 1.7 m (height) x 0.6 m (width) shall be detected at a distance of not less than 1000 m.
  - 5.3.2. Car-sized object

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- 5.3.2.1. Car-sized object of approximate size not less than 4 m (height) x 2.9 m (width) shall be detected at a distance of not less than 1000 m.
- 5.3.2.2. For Car-sized object with lower size the range of detection shall be the function of object height according to the next equation:  
 $range(h) = 1000 * \frac{h}{4}$ , if  $1.2 \leq h \leq 4$ , where h – height of object (minimum object height for detection: 1.2 m).
- 5.3.3. Red railway signals (Red Aspects), Single Yellow signals (Yellow Aspects), Double Yellow signals (Double Yellow Aspects) and Green signals (Green Aspects) shall be detected not less than 1000 m.
- 5.3.4. Cow-sized animal (optionally, if the Zonal Railways provides a properly collected and annotated dataset containing at least 10,000 images of cow-sized animals located within the danger zone or in its immediate vicinity)
- 5.3.4.1. Cows-sized animal of approximate size not less than 1.4 m (height) x 0.8 m (width) shall be detected at a distance of not less than 1000 m.
- 5.3.4.2. For cow-sized animal with lower size the range of detection shall be the function of object height according to the next equation:  
 $range(h) = 1000 * \frac{h}{1.4}$ , if  $0.7 \leq h \leq 1.4$ , where h – height of object (minimum object height for detection: 0.7 m).
- 5.3.5. All dimensions are specified in the plane perpendicular to the direction of loco motion.
- 5.3.6. All distances are specified under normal visibility conditions on straight visible track sections.
- 5.3.7. All distances are specified along the direction of loco motion.
- 5.3.8. Objects may be occluded up to 25% of their total area.
- 5.4. The System shall generate an audio alert signal indicating the presence of objects, specified in Section 5.1 at the specified distances Section 5.3, when such objects are within the danger zone. The system should be able to identify whether the object is on the same track or not (in accordance with Section 5.15). The danger zone is defined as a distance of 2.5 m on each side of the track centerline along which the loco is moving. The distance is measured in the plane perpendicular to the direction of loco motion. The error in determining the presence of an object within the danger zone shall not exceed  $\pm 0.2$  m in the transverse plane when the object is at a distance less than 100 m, shall not exceed  $\pm 0.5$  m when the object is at a distance from 100 m to 500 m and shall not exceed  $\pm 0.7$  m when the object is at a distance more than 500 m.
- 5.5. For Signal Aspects (Red Aspects, Yellow Aspects, Double Yellow Aspects and Green Aspects) detection (and corresponding alerting) shall be provided for the nearest signal ahead in the direction of locomotive movement along the current track, assuming straight-line travel on the same track branch without

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consideration of potential lane changes to any other parallel or adjacent tracks. System shall detect signals located directly above the current track or at a distance of up to 5 m to the left or to the right of the current track center (for determining signal localization and its spatial orientation relative to the track, the System shall utilize data from the Fog Pass Device or from the Fog Pass Signal Asset Database, depending on the selected integration architecture – see Section 5.18). If, according to Fog Pass system data, a Signal is expected ahead along the path of travel (in accordance with the accuracy of the Navigation Module and the Fog Pass system data), but the RSAAS is unable to detect the Signal or its Aspect, an audio alert signal consistent with the alert parameters for the Red Aspect shall be generated to notify the Loco Pilot of this event.

- 5.6. The System shall generate an audio alert signal when an object is detected in the danger zone or Signal Aspect (Red Aspect, Yellow Aspect, Double Yellow Aspect or Green Aspect) is identified (in accordance with the requirements specified in Section 5). The System shall generate an audio alert signal with alert signal repetition frequency (beep rate) as a function of range to the object or aspect:  $F(Range) = 15 - 14 * \frac{D}{Range}$ , Hz (D – Distance to object). To prevent logical errors at extended ranges, the signal characteristics could be fixed at the 1000 m limit; thus, for any distance more than 1000 m, the System could provide an alert corresponding to the 1000 m range. . The system shall generate distinct audio alert signals corresponding to different signal aspects, namely Green, Double Yellow, Yellow, and Red, with Red having the highest priority. The signal type and generation logic may be adjusted (changed) during the development and trial stages upon mutual agreement between the Railways/CRIS and the Vendor.
- 5.7. The audio alert warning of object presence in the danger zone shall automatically be deactivated at zero speed (0 km/h) and activated during motion (if any object, in accordance with Section 5 requirements, is present in the danger zone).
- 5.8. The distance to object (D) measurement accuracy shall be within  $\pm 10\%$  or  $\pm 1$  m (the greater value applies).
- 5.9. The system shall have an anti-blooming mechanism to prevent obscuring of information due to the bright source (headlight of passing locomotive or any other blooming effect). This functionality may be realized through software-level algorithms or integrated image signal processing.
- 5.10. The range of object detection depends on Meteorological visibility. If Meteorological visibility less than 2000 m, then the range of detection, specified in Section 5.1, shall be multiplied by coefficient  $K_{MR}(vis) = \frac{vis}{2000}$ , where vis – meteorological visibility.
- 5.11. The detection ranges given in Section 5.3 may be reduced on curved track sections (curve radius less than 8000 m). In this case the range of detection,

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specified in Section 5.3, shall be determined by the formula  $Distance (Cu) = Cu * 0.125$ , where  $Cu$  – the radius of curvature of the track section between the locomotive and the object (for a section with variable curvature, the minimum value of the radius of curvature shall be applied).

- 5.12. If the current operating conditions correspond to multiple visibility limitation conditions (see sections 5.10, and 5.11), all applicable coefficients and limitations shall be applied.
- 5.13. Detection range in degraded visual environments (adverse weather conditions) of the obstacle and Signal Aspect:

(A) Weather Condition	(B) Train Speed (kmph)	(C) Normal Visibility, m.	(D) Obstacle detection range, m.	(E) Signal Aspect detection range , m.
Clear	Upto 160	Horizon Limited	1000	1000
Mild Fog	Upto 160	300	500	550
Dense Fog	Upto 95	100	250	280
Extreme Fog	Upto 20	5	30	40

- 5.13.1. Train speed ranges given at column (B) are indicative, specific speed(s) will depend upon the conditions and visibility prevailing at the time of field trials in dynamic condition.
- 5.13.2. Normal Visibility at column (C) should be referred as naked eye visibility of a person with normal vision for static trials and dynamic condition.
- 5.13.3. To validate the above functional requirement, trials will be conducted in the real field condition and parameters will be recorded. The Trials will be carried out across the regime at different points according to the prevailing foggy condition and the corresponding values for column (D) and (E) of above table shall also be recorded.
- 5.13.4. However, the trials in each fog regime shall be conducted up to the lowest achievable Normal visibility towards the lower limit of the respective range of fog regime (Column C).
- 5.13.5. Vendor has to arrange for necessary measuring and test equipment for functional trials.
- 5.14. Precise data regarding the reduction in visibility range for objects and signal aspects under adverse operating conditions (see sections 5.9, and 5.11) shall be evaluated based on the results of field trials under actual operational conditions.

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- 5.15. The System shall detect objects along the current track, assuming straight-line travel on the same track branch without consideration of potential lane changes to any other parallel or adjacent tracks. Note: Optionally, if the Zonal Railways provides information about the state of railway turnouts (through integration with a system providing such information), this information will be incorporated in the System's logic.
- 5.16. The system shall operate at speeds up to 160 km/h.
- 5.17. The number of false positives shall be not more than 3 per 100 passed km (detections and alerts meeting the requirements specified in Section 5 shall be considered correct). The number of false negatives shall be zero (the validation criteria for correct system reaction are detailed in Section 14.4).
- 5.18. Integration with the Fog Pass system shall be established for signal location data for determining Red Aspects, Yellow Aspects, Double Yellow Aspects and Green Aspects localization and its spatial orientation relative to the track as per the functionality broadly based on the Fog Pilot Assistance System for Safety (FogPASS) Specification number: RDSO/SPN/201/2010, Version-2.0. The specific integration methodologies — involving either the direct utilization of data from the Fog Pass Device or the Fog Pass Signal Asset Database — shall be mutually agreed upon between the Zonal Railways/CRIS and the Vendor. The Zonal Railways/CRIS shall be responsible for providing all requisite information necessary for the execution of these works, including but not limited to: comprehensive API documentation, Interface Control Protocols, Data Formats and communication standards, related technical specifications for system interoperability. In subsequent phases of the project, the Fog Pass system shall be integrated into the RSAAS architecture. The definition of the scope of work, including all technical and commercial terms, shall be subjected to separate negotiations between the Vendor and the Zonal Railways/CRIS .
- 5.19. System sensitivity
- 5.19.1. In case a thermal imaging camera is used, the Noise Equivalent Temperature Difference (NETD) of the system should be lower or equal to 45 mk in the full operating temperature range. If the recommended NETD is not used, Vendor may furnish the NETD for selected camera with justification to meet the functional requirement with their offer for their design appraisal

## 6. Environmental condition

- 6.1. Atmospheric temperature – from -20°C to + 70°C.
- 6.2. Humidity: 20 – 95 %, with extended operation possible up to 100% in specific environmental conditions (fog, dew).
- 6.3. Altitude – up to 1800 m above mean sea level.
- 6.4. Rainfall – Very heavy in certain areas.

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- 6.5. Atmospheric Conditions – Extremely dusty and desert terrain in certain areas. The dust content in air may reach a high value of 1.6 mg / m<sup>3</sup>. In many iron ore and coal mine areas, the dust concentration is very high affecting the filter & air ventilation system.
- 6.6. Coastal area – Humid & salt laden atmosphere with maximum pH value of 8.5, sulphate of 7 mg per liter, maximum concentration of chlorine 6 mg per liters and maximum conductivity of 130 micro siemens/cm.
- 6.7. Vibration – The equipment, system and their mounting arrangement shall be designed to withstand satisfactorily the vibration and shocks encountered in service as specified in IEC 61373.
- 6.8. Wind speed – High wind speed in certain areas, with wind pressure reaching 150 kg/m<sup>3</sup>
- 6.9. Atmospheric temperature – maximum temperature of metallic surface under the sun 75°C & minimum temperature -10°C (Also snow fall in certain areas during winter season).
- 6.10. The unit shall meet the requirements of RDSO specification no. ELRS/SPEC/SI/0015/ Rev 1-October 2001 for “Reliability of Assurance specification for Electronic components for use in rolling stocks.”
- 6.11. Rolling Stock: EN 50155:2007 / IEC 60571 or latest compliance (shock, vibration, temperature, EMC)

## 7. Technical Requirement

- 7.1. The system should be user friendly as well as hands free to the extent possible.
- 7.2. The System shall be powered from the locomotive's nominal 110V DC battery supply. System shall be designed to minimize the power requirement. The electromagnetic compatibility inside the locomotive shall be as per IEC-62236. The hardware design shall be highly rugged for external environment and resilient to voltage fluctuations as specified in IEC 60571.
- 7.3. Hermetic ceiling shall be provided for critical components with minimum IP-65 level for indoor equipments and IP-67 for outdoor equipments as per IEC-60529 standard.
- 7.4. Every component of the system shall be mounted on locomotive itself. The system shall be self-sufficient and there shall not be any installation on the track side.
- 7.5. Multispectral Camera (Including VIS Camera) should be installed at suitable location Mounting arrangement of camera shall be such that clear view is available and it is robust to sustain and isolate jerk and vibration experienced while locomotive running.

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- 7.6. System components shall be installed on the locomotive jointly by representatives of the Vendor and the Zonal Railways/Nominated Loco sheds. The schedule and timeline for allocating locomotives for system component installation shall be pre-agreed between the Zonal Railways/Nominated Loco sheds and the Vendor. Nominated Loco sheds for conducting POC shall be communicated to the successful bidder.
- 7.7. Proper vibration isolation technology should be provided for the system at physical level.
- 7.8. Video stabilization algorithms to stabilize real time videos may be provided, if required.
- 7.9. Device must work in all types of weathers encountered in India, including rain, fog conditions, etc., as mentioned in section 6.
- 7.10. The system must record Camera recordings in clear video format for post-event analysis. The storage capacity must be sufficient to store at least 15 days of video. Industrial grade Solid state drive should be used for storing the data.
- 7.11. The video so stored as above must be in a format that can be copied to a portable Hard Disk (USB) or a USB flash drive, or to a connected laptop using the software installed on it. The final solution is determined by the Vendor and approved by the Zonal Railways/CRIS. The quality of the transferred video must be as clear as the original video.
- 7.12. The system shall run built in self-test on power up, and could give warning to the driver if the system fails and is not functioning as expected.
- 7.13. If the system device fails, then it should give a positive indication to the driver/loco pilot that the system has become inoperative/ unreliable/ defective. This should be an act of positive alarm to the driver. Such alarm/warning should be acknowledged by the driver through a positive act of acknowledgement.
- 7.14. Power up time shall be less than 2 minutes.
- 7.15. The overall dimension and weight of the equipment should be able to be accommodated in the space available in the driving cab of both diesel and electric locomotives, without causing any inconvenience to the driver in having clear view ahead and discharging his functions.
- 7.16. The components installed at the locomotive's exterior shall not infringe the maximum moving dimension The Drawing indicating maximum moving dimension of loco is attached at Annexure-2.
- 7.17. Anti-pilferage and vandal proof mechanism should be provided for external equipment.
- 7.18. Connectors used with RSAAS should be compliant to MIL standard or equivalent.

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## 8. Life cycle management

The equipment supplier shall ensure that the lifecycle requirements of the equipment be met as detailed in the paragraphs below

- 8.1. Expected life
  - 8.1.1. The expected life of the equipment shall be 12 years or more.
- 8.2. Support during lifetime
  - 8.2.1. The equipment manufacturer shall ensure that the following support is available on demand during the equipment lifetime:
    - 8.2.1.1. Service/spares support for the equipment
    - 8.2.1.2. Options for comprehensive maintenance contract
    - 8.2.1.3. Modifications in equipment design to meet new requirements or to improve reliability
  - 8.2.2. The options for demanding these support services shall be reserved by the Indian Railways and the equipment manufacturer shall provide the same on demand.
  - 8.2.3. *Note. Cost of the services shall be determined through a mutually acceptable process between the manufacturer and the users on the Indian Railways*
- 8.3. End of equipment life management
  - 8.3.1. The equipment manufacturer shall provide options to upgrade/refurbish equipment at the end of life of the equipment when requested by the Indian Railways.

## 9. Safety requirements

- 9.1. The equipment shall meet all statutory and regulatory criteria required for public safety. The device must be safe in all respects to humans-both to locomotive personnel and to trespassers on railway track who are being scanned and imaged.

## 10. Tests and Trials

- 10.1. Test and Trials shall be conducted with the system mounted on locomotive.
- 10.2. Tests and Trials shall be conducted in accordance with Annexure 1.

## 11. Training

- 11.1. The Vendor shall conduct training for the Railway staff on system operation. The number of Zonal Railway staff to be trained and the timing

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of the training shall be agreed upon between the Vendor and the Zonal Railways/CRIS.

## 12. Warranty

- 12.1. The complete system with controls shall be warranted for satisfactory and trouble-free operation in conformity with the “Special Condition of Tender” All aspects of workmanship and design shall be covered by this warranty. The supplier shall immediately provide arrangement for rectification of failures reported under warranty.
- 12.2. Warranty period of any equipment of the system may be extended as per mutual agreement between purchaser and supplier if the equipment has undergone major design modifications during the warranty period.

## 13. Documents

- 13.1. The following documents shall be provided by the Vendor:
  - 13.1.1. Functional Requirement Specification
  - 13.1.2. Operating Manual
  - 13.1.3. Maintenance Manual
  - 13.1.4. Documentation for the Overall System:
    - 13.1.4.1. Bill of Materials (BOM) / System Specification
    - 13.1.4.2. Installation Drawing
    - 13.1.4.3. Installation Manual
    - 13.1.4.4. Connection Diagram and List of Components
  - 13.1.5. Documentation for Components and Sub-assemblies (where applicable, to be determined by the Supplier)
    - 13.1.5.1. Sub-assembly Bill of Materials (BOM)
    - 13.1.5.2. Assembly Drawings
    - 13.1.5.3. Detail Drawings
    - 13.1.5.4. Circuit Diagram (Schematic) and List of Components
    - 13.1.5.5. Wiring Diagram and List of Components
  - 13.1.6. Design documentation for the fabrication of test obstacles.

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## **14. Annexure 1. Assessment of compliance with the specified requirements**

- 14.1. Assessment shall be conducted both at the test facility and under real operating conditions.
- 14.2. Assessment at the test facility
  - 14.2.1. Prior to the start of testing, following objects shall be prepared
    - 14.2.1.1. Human dummy/mock-up of approximate size not less than 1.7 m (height) x 0.4 m (width).
    - 14.2.1.2. Human dummy/mock-up of approximate size not less than 0.7 m (height) x 0.4 m (width).
    - 14.2.1.3. Bike or motorbike with a rider dummy/mock-up of approximate size not less than 1.7 m (height) x 0.6 m (width).
    - 14.2.1.4. Car dummy/mock-up of approximate size not less than 4 m (height) x 2.9 m (width).
    - 14.2.1.5. Car dummy/mock-up of approximate size not less than 1.2 m (height) x 0.9 m (width).
    - 14.2.1.6. Cow dummy/mock-up (optionally) of approximate size not less than 1.4 m (height) x 0.8 m (width).
    - 14.2.1.7. Cow dummy/mock-up (optionally) of approximate size not less than 0.7 m (height).
    - 14.2.1.8. A railway signal with the capability to activate and deactivate a Red aspect, Yellow Aspect, Double Yellow Aspect and Green Aspect (if such signal is not available at the test site).
  - 14.2.2. Test dummies shall be built in accordance with Design documentation (Section 13.1.6) and in conformity with the requirements in section - 5.
  - 14.2.3. Testing shall be performed for the objects listed in Section 14.2.1.
  - 14.2.4. Testing shall be performed by a committee including representatives from both the Zonal Railways/CRIS and Vendor. Test results shall be documented in a test report.
  - 14.2.5. Testing of the system characteristics specified in Section 5 shall be conducted under both static and dynamic conditions on a straight track section (radius of curvature not less than 8000 meters), with a minimum length of 1100 m, under normal lighting conditions and meteorological visibility (greater than 2,000 m).
  - 14.2.6. Test success for each object shall be evaluated in accordance with Section 14.4. In case of disagreement among committee members regarding test results, verification with the corresponding object type may be repeated. Additionally, analysis of test results based on System logs recorded during testing is acceptable (in this case, the Vendor's representatives shall be provided access to the System to retrieve the logs).

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#### 14.2.7. Static testing

14.2.7.1. Before starting testing, the Vendor's representative must activate the audio warning function at 0 km/h speed.

14.2.7.2. Before starting testing, the loco shall move forward and travel at least 3 metres in the direction of the objects to activate the sensor block directed toward the objects.

14.2.7.3. During static testing, objects shall be placed within the danger zone defined in Section 5.4, at a distance not exceeding 1000 m from the loco equipped with the System.

14.2.7.4. During static testing, Railway Signal shall be placed in according with zones defined in Section 5.5, at a distance not exceeding 1000 m from the loco equipped with the System. Signal must be pre-configured in the Fog Pass system (see Section 5.5) (alternatively, the Vendor may utilize simulated data).

#### 14.2.8. Dynamic testing

14.2.8.1. Before dynamic testing, objects shall be placed within the danger zone defined in Section 5.4, in the direction of movement, at a distance at least 1100 m from the loco equipped with the System.

14.2.8.2. Before dynamic testing, Railway Signal shall be placed in according with zones defined in Section 5.5, in the direction of movement, at a distance at least 1100 m from the loco equipped with the System. Signal must be pre-configured in the Fog Pass system (see Section 5.5) (alternatively, the Vendor may utilize simulated data).

14.2.8.3. Before testing with each object, the loco shall return to the initial position at a distance of at least 1100 m from the installed test object or Railway Signal.

#### 14.3. Real operating conditions testing

14.3.1. Testing under real operating conditions shall be conducted as part of normal train operations. The timing and schedule of such testing shall be pre-agreed between Zonal Railways/CRIS and Vendor representatives.

14.3.2. In case of System operational issues detected during testing, a record of such event with the time and, if possible, a brief description shall be entered into the test log. This log shall be provided daily to the Vendor's representatives.

14.3.3. The Vendor shall develop and provide a "Loco Pilot's Log Instruction" detailing the procedure for manual recording of System events. In case of any System operational issues detected during testing, the client's personnel (e.g., Loco Pilot) shall record such events in a Test Log in accordance with said Instruction.

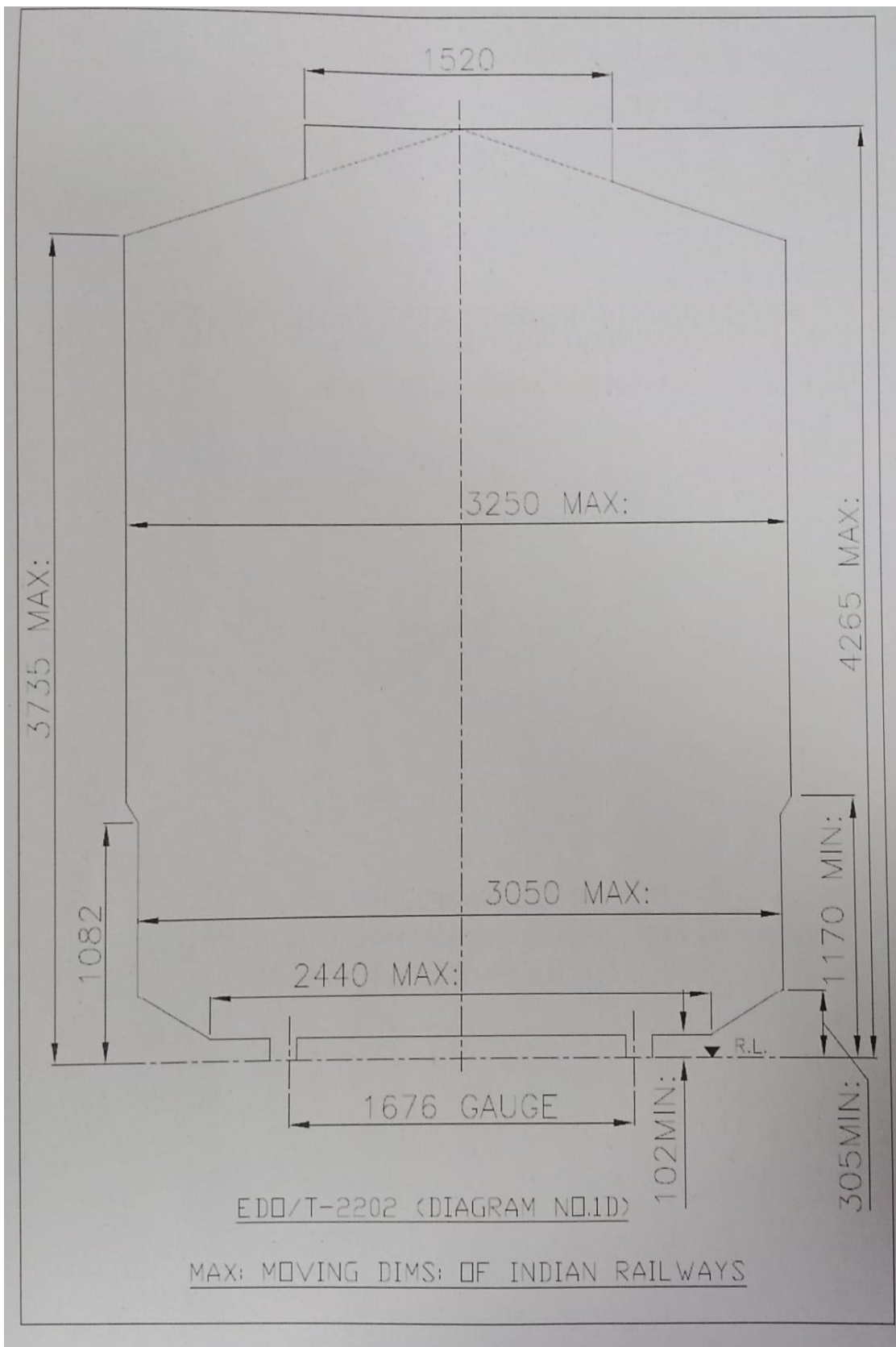
14.3.4. The Vendor shall submit a weekly summary report on the System's performance to the Zonal Railways/CRIS. The report shall be prepared

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- based on analysis of system logs, manual recording logs and test records (logs).
- 14.3.5. The Vendor's representatives shall be provided access to the System to retrieve the logs.
  - 14.3.6. Correctness of system operation shall be evaluated in accordance with Section 14.4.
  - 14.3.7. The System's overall performance assessment and statistical data shall be formulated based on the Vendor's reports and their thorough examination. The resulting test protocol shall be agreed upon by representatives of the Vendor and the Zonal Railways/CRIS .
- 14.4. The System reaction shall be considered correct and successful if the corresponding audio alert is generated for at least 90% of the period during which the object is present in the danger zone or the Signal Aspect is within the sensor's line of sight (in accordance with the requirements specified in the Section 5).

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**15. Annexure 2. Maximum moving dimension of loco**



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## 16. Annexure-3 Sensor Configuration

Preliminary sensor configuration (Optical Camera and Thermal Imaging Camera) for the RSAAS project

### Optical Camera

- Resolution: 3840H\*2160V
- Frame Rate: 3840\*2160@30fps
- Sensor OMNIVISION: 8.3MP OX08B40 RGGB
- ISP: GW5300
- Output data: YUV422@8bit
- Serializer MAXIM MAX9295A
- Sensor Type : Rolling Shutter
- Operating temp.range: -20°C to +70°C
- Dimensions : 40mm\*40mm\*23mm

### Thermal Imaging Camera

- Sensor: Uncooled Vanadium Oxide (VOx) microbolometer, 1280 x 1024 pixels, 12 μm pitch.
- Spectral Range: Long-wave infrared (LWIR), 8 to 14 μm.
- Sensitivity (NETD): ≤ 40 mK @ 25°C.
- Frame Rate: 30 Hz.
- Field of View (H x V): 17.5° x 14° (±10%).
- Image Functions: Automatic/Manual NUC, Digital Zoom (1-8x), Digital Noise Reduction.
- Interfaces: Gigabit Ethernet (video/data)
- Power Supply: 6 – 24 VDC (12 VDC nominal).
- Power Consumption: ≤ 3.5 W (without heater), up to 45 W (with heater).
- Protection Class: IP65.
- Operating Temperature: -20°C to +70°C
- Dimensions (W x H x D): 90 mm × 82.5 mm × 146 mm (±2 mm).
- Weight: ≤ 1.3 kg (without cable).
- Reliability: MTBF 100,000 hours.

Note:-The input supply shall be taken from locomotive which is 110V DC +/- 35V in electric locomotives

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## 17. Annexure-4 Computation unit configuration

### Computation Unit shall have following:

1. Industrial Edge AI Computing Unit (Rugged Enclosure Included)
2. CPU support: Intel® Xeon® E and Intel® 14th GenCore or similar
3. GPU support: NVIDIA® RTX A6000 or similar, with dedicated GPU bracket
4. Multi-Camera Frame Grabber / Capture Card
5. Networking Module (miniPCIe or Equivalent)
6. PoE+ Ethernet Adapter (PCIe-Based or Equivalent)
7. Memory: up to 128 GB DDR5 (ECC/non-ECC)
8. Storage SSD (2 TB)
9. Storage SSD (1 TB)

#### 1. Industrial Edge AI Computing Unit (Rugged Enclosure/chassis : Neosys Nuvo-8108GC-QD or similar Included) :

- Functional Role: Industrial grade edge AI computing unit (with rugged enclosure as a part of the Computing Unit) for real-time multi-camera video ingestion, processing, AI inference, storage, and network transmission in rugged field environments.
- Operating temperature:  $-25^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$  (rugged operation, per vendor spec)
- Reliability / ruggedness: vibration 3 Grms (5–500 Hz, 3 axes) and shock per MIL-STD-810G; humidity 10–90% non-condensing

#### 2. CPU support : Intel® Xeon® E and Intel® 14th GenCore or similar

- Cores / threads: 8 Cores / 16 threads
- Base / turbo: 3.40 GHz / up to 5.00 GHz
- Cache / TDP: 16 MB cache; 80 W TDP
- Operating temperature (thermal limits): Tcase  $\sim 73^{\circ}\text{C}$ , Tjunction  $\sim 100^{\circ}\text{C}$  or better
- Reliability angle (platform-level): server/workstation-class CPU family used with ECC-capable platforms (ECC enablement depends on system configuration)

#### 3. GPU Support : NVIDIA RTX A6000 or similar, with dedicated GPU bracket

- Architecture: NVIDIA Ampere (pro RTX) or similar
- VRAM: 48 GB GDDR6, ECC supported
- Memory interface / bandwidth: 384-bit / 768 GB/s
- Operating environment (ambient):  $0^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$  (short-term up to  $+55^{\circ}\text{C}$ ), humidity 5–85% operational

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- Reliability: MTBF reported as >800,000 hours

#### **4. Multi-Camera Frame Grabber / Capture Card - CCG3-8H (CoaxCapture GMSL Video Capture Card Gen2) or similar**

- Function: multi-camera capture (variant supports 8 camera inputs)
- Supported camera resolution: 1–8 MP; bit depth includes YUV422 (8-bit) and RAW (8/12/16-bit)
- Operating temperature: –20°C to +70°C; storage –40°C to +80°C
- Humidity: 5–90% RH non-condensing (operating)
- Reliability: MTBF: 5 years (as specified in datasheet)

#### **5. Networking Module (miniPCIe) — Innodisk EMPL-G201-W2 (mPCIe to Dual GbE LAN Module or similar)**

- Interface: PCI Express 2.0 x1 (miniPCIe); 2× GbE (RJ45)
- Power: max 1.485 W (3.3 V, 450 mA)
- Operating temperature: –40°C to +85°C (Wide Temp, W/T); storage –55°C to +95°C
- Reliability / ruggedness: vibration 5G (7–2000 Hz), shock 50G @0.5 ms

#### **6. PoE+ Ethernet Adapter (PCIe-Based or Equivalent) - Neousys PCIe-PoE312M (M12 X-coded) or similar**

- Ports / NIC: 4× GbE via Intel® I350 (server-grade), supports IEEE 1588
- PoE: IEEE 802.3at (PoE+), up to 25.5 W per port
- Operating temperature: 0°C to +55°C with airflow
- Reliability note: rugged surveillance/edge card positioning

#### **7. Memory 2 × 32 GB Kingston KSM56T46BD8KM-32HA or similar**

- Type / form factor: DDR5-5600 MT/s ECC On-DIMM (262-pin)
- Capacity / rank: 32 GB, 2Rx8
- Operating temperature: 0°C to +95°C
- Storage temperature: –55°C to +100°C
- Reliability feature: ECC (On-die ECC + Side-band ECC)

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### 8. Storage SSD (2 TB) — Innodisk mSATA 3TE7, 2TB or similar

- Form factor / interface: mSATA (MO-300), SATA III 6.0 Gb/s
- Capacity: up to 2TB (order option exists for 2TB)
- Performance (max): Sequential R/W 550 / 510 MB/s
- Endurance: P/E 3,000, TBW (max) 2,400 TB
- Operating temperature: Standard 0 - 70°C, Industrial -40 to 85°C
- Reliability: MTBF > 3,000,000 hours

### 9. Storage SSD (1 TB) — Innodisk M.2 (P80) 4TG2-P, 1TB (PN: DGM28-01TDP1KCCEF / wide-temp option DGM28-01TDP1KWCFH) or similar

- Form factor / interface: M.2 2280 (M-Key), PCIe Gen4 x4, NVMe 1.4
- Flash: 3D TLC, LDPC ECC
- Performance (max): Seq Read/Write 6950 / 4700 MB/s
- Endurance: TBW (Max.) 8444 TB, P/E 3000
- Operating temperature: Standard 0 - 70°C, Industrial (Wide Temp) -40 to 85°C
- Storage temperature: -40 to 85°C
- Reliability / rugged: MTBF > 3,000,000 hours, Vibration 20G (7–2000Hz), Shock 1500G @0.5ms

#### Note:

1. All equipment shall be industrial-grade and suitable for 24×7 continuous operation.
2. OEM must provide environmental compliance certificates.
3. MTBF documentation shall be submitted where available.
4. All components must be mutually compatible and validated by the bidder.