WaveTrain Systems
Level Crossing Warning System

MTM Compatibility Report

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## Glossary of Terms

Terms, abbreviations and acronyms used in this document are listed in the following table:

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<tr>
<th>Term/Accronym/Abbreviation</th>
<th>Definition</th>
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<tr>
<td>AREMA</td>
<td>American Railway Engineering and Maintenance of Way Association</td>
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<td>ARO</td>
<td>Accredited Rail Operator</td>
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<tr>
<td>CBI</td>
<td>Computer Based Interlocking</td>
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<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
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<td>Dark Mode</td>
<td>Defined as a state of the LCWS when the system is unable to output a valid signal to the end users. This might be caused by irregular conditions (e.g. loss of external power, other activities on the railway line).</td>
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<tr>
<td>EMC</td>
<td>Electromagnetic Compatibility</td>
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<td>EMI</td>
<td>Electromagnetic Interference</td>
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<td>EMU</td>
<td>Electric Multiple Unit</td>
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<tr>
<td>FMECA</td>
<td>Failure Modes, Effects &amp; Criticality Analysis</td>
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<tr>
<td>GSM</td>
<td>Global System for Mobile Communications</td>
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<tr>
<td>IP</td>
<td>Ingress Protection</td>
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<tr>
<td>ISA</td>
<td>Independent Safety Assessor</td>
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<td>LCWS</td>
<td>Level Crossing Warning System</td>
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<tr>
<td>MOXA</td>
<td>Provider of products for industrial networking, computing, and automation</td>
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<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
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<td>MTM</td>
<td>Metro Trains Melbourne</td>
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<tr>
<td>MTTR</td>
<td>Mean Time To Repair</td>
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<tr>
<td>NR</td>
<td>Network Rail (UK)</td>
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<tr>
<td>RAMS</td>
<td>Reliability, Availability, Maintainability and Safety</td>
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<tr>
<td>ROHS</td>
<td>Restriction of Hazardous Substances</td>
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<tr>
<td>Side-shift</td>
<td>Function of determining of the direction of incoming sound, by software based Bayesian statistical analysis</td>
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<td>SIL</td>
<td>Safety Integrity Level</td>
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<td>SMS</td>
<td>Short Message Service</td>
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<td>SRAC</td>
<td>Safety Related Application Conditions</td>
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<tr>
<td>TCB</td>
<td>Trackside Connection Box</td>
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<tr>
<td>THR</td>
<td>Tolerable Hazard Rate</td>
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<tr>
<td>V/Line</td>
<td>Operator and maintainer of Victorian regional and country passenger network</td>
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<tr>
<td>VRIOGS</td>
<td>Victorian Rail Industry Operators Group Standards</td>
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<td>WEEE</td>
<td>Waste Electrical and Electronic Equipment</td>
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<td>WTS</td>
<td>WaveTrain Systems (designer and manufacturer of LCWS)</td>
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1. **Background**

The WaveTrain Systems (WTS) Level Crossing Warning System (LCWS) became officially known to MTM personnel during a visit to MTM in July 2013. Subsequently, an agreement was reached between WTS and MTM to procure an instance of the product with the potential to conduct a suitability trial at a level crossing site on the Frankston to Stony Point line.

WTS have a commissioned LCWS site in the UK, and a number of installed trial sites in UK, Norway, Pilbara Australia and South Africa of LCWS up to version 1.1. WTS have recently achieved SIL2 safety rating for LCWS version 1.3 from Lloyds ISA.

Based on previous and new information, MTM have requested that a review of the LCWS documentation including test data from installed sites be conducted and submitted (this report), to assist MTM in the decision of how to proceed with the evaluation of the WTS LCWS.

2. **Scope**

This report provides a summary of the WTS LCWS, including a description of the system and how it operates, and its compatibility with “typical” level crossings on the MTM rail network. The report also summarises the reliability of the LCWS based on data collected for installed operational sites on Network Rail (NR), UK.

Safety is covered in terms of current and proposed SIL certification, and also based on data collected from installed operational sites.

Subsections are included to discuss availability, maintainability, cost benefits, EMC and comparisons with alternative detection technology such as axle counters and predictors.

This report is intended to provide a summary of the above topics. An in-depth analysis, including a full audit and testing of LCWS against Victorian and other referenced standards would be the subject of a future trial and Type Approval stage.
3. System Description

The LCWS system is based on measuring the sound waves induced by oncoming trains through sensors attached to the track. The sensors transmit an electronic signature representation of the sound waves to a Control Unit, which constantly analyses the data. If the sounds are identified as an approaching train a prediction of when the train will pass takes place.

When the predicted arrival time is within a pre-configured defined range, outputs to warning devices (lights, bells, booms, pedestrian gates) are activated to warn the level crossing users. The defined range is configured to match the required warning times.

When the train has passed, which is also determined by the sound picked up by the sensors, the outputs are deactivated. The system does not give light signals to the train driver, nor is it interfaced to the railway signalling systems or infrastructure.

The configuration of light signals is configurable, including the installation or not of a white signal light to indicate that the system is operational.

The basic LCWS configuration has one Main Assembly, containing two Control Units, and two Sensor Units, both on the same rail, connected to each Control Unit. The red warning lights and the white indicator lights are not part of the LCWS product. They are provided by the client and connected to the LCWS signal interface. Warning devices other than lights can be used, such as audible warning devices.

When no oncoming trains are detected, the warning indicator signals are in an "off state". The warning indicators only operate when a train is approaching. In this state there is a failsafe system running so that the Control Unit detects loss of contact with the warning indicators.

The Control Units also monitor their own sensors and internal operations, and are available to indicate a failure of the system. The failure is logged to a file, and a notification can optionally be sent to external devices or communication systems. The GSM phone network is used to report fault messages (email...
plus optional SMS) to maintainers. The log file can also be downloaded by maintainers via the GSM network.

Technically, only one sensor on a track is required to identify the presence of a train, however two sensors must be in operation on a single rail for the Control Unit to determine from which direction a train is approaching, and to which direction a train is departing. For this reason, the LCWS has two Control Units with two sensors each in order to provide redundancy and train direction. Using this arrangement, if any single sensor fails, the system will continue to operate normally. If two sensors for the same Control Unit fail, then again the system will operate normally.

If however, two sensors for different Control Units fail, or more than two sensors fail, the system is unable to operate and will enter fail-safe Dark Mode. A message will be automatically issued to inform the responsible maintenance team.
4. **Compatibility with “Typical” MTM level crossings**

The LCWS was first considered by MTM for the crossings on the single-track, non-electrified Frankston to Stony Point line. However, as these crossings have subsequently been upgraded to use axle counters, there is now very limited opportunity to use LWCS on single-track level crossings sites within the MTM rail network.

For the wider MTM rail network the road crossings are on multi-track, electrified lines and include a number of the following characteristics:

- Crossing with booms, lights, bells and pedestrian gates
- Multi-track, with holding sections
- Track circuit triggered
- Stopper and express moves
- Station within the crossing minimum warning distance
- Signal(s) protecting the crossing
- 1500VDC traction
- Mixed traffic (suburban EMU, diesel loco hauled freight, diesel V/Line passenger

Level crossings within the MTM rail network are expected to meet the requirements of VRIOGS 012.0 section 4.5 (Victorian Signalling Principles – Level Crossings). A cursory review of the LCWS against this standard shows that the LCWS can be configured to meet the following level crossing requirements of this standard. This includes:

- Minimum warning time of 25 seconds.
- The warning time shall be increased for road crossings by 0.35 seconds for each metre of crossing width over 10 metres and for pedestrian crossings by 1.35 seconds for each metre over 10 metres between points of refuge.
- Operation of the level crossing protection shall be continuous.
- An audible warning device is provided as part of the level crossing protection system for flashing lights and boom barriers.
- The flashing lights and bell operate until the rear of the train has cleared the crossing.
- The boom barrier equipment operates as follows during the warning time:
  - Flashing light and bell activation.
  - After 7 seconds of flashing light and bell operation the boom barrier arms commence to lower.
  - The boom barriers shall reach the fully lowered position a period not greater than 12 seconds after they commenced to lower.
- Active protection provided at pedestrian crossings to provide users of the crossing warning of the approach of trains.

The following requirements of VRIOGS 012.0 section 4.5, would require further investigation and/or testing to confirm LCWS compliance:
Active Advance Warning Signs (AAWS) may be required at some level crossing sites in order to provide an early indication, which are commanded to flash by the level crossing detection system at a predetermined time period before the level crossing lights and bells begin operating.

Interlocking between signals and the level crossing protection systems when signals are located within the approaches of a level crossing.

Express/stopping selection provided when a platform is on the approach side of a level crossing fitted with boom barrier protection and is in close proximity to the crossing.

Traffic light co-ordination with the level crossing where road intersections with traffic lights or pedestrian road crossings occur near a railway level crossing.

The LCWS has not yet been formally site tested for multiple track installations. Multi track testing has been conducted in a laboratory, however, ISA certification for LCWS is currently limited to single track installations. Therefore the following requirement of VRIOGS 012.0 section 4.5, related to multi track installations would not be covered by version 1.3 of LCWS.

The holding sections are of sufficient length to ensure that with a second train approaching at line speed just about to occupy the holding section, the boom barriers will be in the raised position for at least 25 seconds before the flashing lights and bells begin for the second train.

### 4.1. Minimum Warning Times

Data has been collected for the LCWS installed site at Coltishall Lane in Norwich UK. Figure 1 below shows the warning times for the crossing over an 8 month period. At this crossing the minimum warning time is set to 21 seconds, based on maximum line speed calculations from NR.

On this crossing the line speed is 100 mph (160 kph) and there is a mixture of normal passenger trains and some freight trains going out to the port. Freight trains have a maximum line speed of 60 mph (96 kph), hence the variation of warning times shown. The results show only two events where the warning time was under 21 seconds (one at approx. 16 seconds and the other at approx. 18 seconds) out of a total of 8186 trains. This equates to 99.98% being at or above the minimum warning time.

This crossing is on a single track. There are three locations in the UK where LWCS is installed at sites with double track, however these sites are yet to be commissioned.
4.2. Type of traction power where installed

There are three locations in the UK where LWCS is installed at sites with 25kV AC overhead electrified lines, however these sites are yet to be commissioned. One of these sites, “Golf Links”, is operating under pre-commissioning trial and is collecting data. The Coltishall Lane site in section 4.1 is not on an electrified line.

NR are also in the process of installing sites where the traction system is 750VDC third rail.

For the LCWS site in South Africa the traction system is overhead electrified line, however the voltage used has not been advised by WTS.

For installation of LCWS on the MTM rail network, site testing would be recommended to confirm there are no compatibility issues with the 1500V DC traction environment.
5. **LCWS Limitations**

LWCS has a number of limitations [15], which are listed below:

- LCWS requires continuously welded rails between the sensors and the point at which a train must be heard to provide the minimum warning time. An exception to this is for new track with new joints, where the LCWS will give adequate warning times provided that the differences are taken into account in the location design and placement of sensors.

- There should not be any turnouts (points) between the sensors and the minimum warning distance.

- If a station is within the minimum warning distance and a train stops and then heads back in the opposite direction the LCWS will enter the system fail-safe state Dark Mode. To recover from Dark Mode the LCWS will execute an automatic reset, either on the next train approaching or after a pre-configured time period.

- Controlled signals within the minimum warning distance may cause long warning times and eventually cause the LCWS to enter the system fail-safe state “Dark Mode” in the cases where trains stop for long periods before traversing the level crossing.

- GSM coverage is required at the site in order to transmit critical messages via the public phone network. Failure or outages of the GSM network will not impact the normal operation of the crossing.

- The up and down line speeds on the same track should be similar to ensure consistent warning times.

- Heavy freight trains (e.g. trains carrying iron ore) may cause sound levels outside the scope of the normal configuration of the LCWS sensor unit, and therefore cause longer extinguish times which might lead the LCWS to enter into fail-safe state Dark Mode. This limitation should not apply to the MTM rail network.

There are also some conditions for which LCWS has not been formally tested:

- High leaf fall sites where there may be sliding wheels instead of rotating. Testing by placing a large amount of leaves on the rail has not been conducted, however in both Norway and the UK there are many trees alongside the rails where the LCWS has been tested and commissioned, without any issues caused by leaf coverage.

- Rail Head Treatment Trains (RHTT) applying water jets to rails at high pressure. High water pressure is used to clean ice from rails in Norway, and an ultrasonic rail inspection train has been running past the LCWS locations in the UK. No issues have been reported due to these events.

- Distance to maintenance works such as tamping. During tamping, the LCWS must be set in manual mode according to the operational and maintenance manual.

- Rail grinding within hearing distance of LCWS. During rail grinding and re-railing, the LCWS must be set in manual mode according to the operational and maintenance manual. This is the case at the Rio Tinto LCWS sites where re-railing works are currently being conducted.

The above conditions, if relevant, should be considered if conducting any potential site trial on the MTM network.
6. Comparison with alternative detection technology

6.1. Track circuits

Track circuits provide a fixed point at which the crossing will be activated. This has an advantage that minimum warning times are assured providing trains are running within the line speed, however the slower the train is travelling the longer the warning time. In comparison, the LCWS calculates the crossing activation time based on the train sound signature and pre-configured minimum warning time. This should result in more consistent warning times for trains travelling at different speeds.

When installed for level crossing detection, track circuits need to be installed for the island track, for the approaches, and if required also for the holding sections. This means that cables need to be installed, or existing cables allocated, from each track circuit transmitter and receiver to the level crossing evaluator (e.g. relay or CBI location case). The LCWS has the advantage that all components are installed within close proximity to the level crossing itself. There is no need for long cabling between the level crossing and the sensors.

As track circuits are normally installed in a non-redundant configuration, if a track circuit or its cabling fails, the whole track section becomes occupied until the fault is repaired. In comparison, the LCWS has redundant sensors such that a failure of one sensor will not impact the operation of the level crossing.

Track circuits are sensitive to the ballast resistance, which needs to be within a specific range. In comparison, the LCWS has no dependency on ballast resistance.

If the up and down line speeds on the same track are different then the approach track circuits can be made different lengths on the up and down side to provide more consistent warning times. In comparison, the LCWS requires the up and down line speeds to be similar to ensure consistent warning times.

6.2. Axle counters

When installed for level crossing detection, axle counter heads need to be installed for the island track, at the outer boundaries of the approaches, and if required also for the holding sections. This means that cables need to be installed, or existing cables allocated, from each of the head TCBs to the axle counter evaluators. The LCWS has the advantage that all components are installed within close proximity to the level crossing itself. There is no need for long cabling between the level crossing and the sensors.

Axle counter heads are can be installed in either a redundant or non-redundant configuration. In a non-redundant configuration, if an axle counter head or its cabling fails, the whole track section becomes occupied until the fault is rectified. In comparison, the LCWS is always configured with redundant sensors such that a failure of one sensor will not impact the operation of the level crossing.

Axle counters require a reset whenever their wheel count becomes inconsistent. This can occur due to a miscount, road rail vehicle getting on or off track, or interference from metal objects. The LCWS system has been tested for interference from sounds not emitted by trains, and is proven not to interpret these as a train approaching. The LCWS will also execute an automatic reset following an event such as a train stopping before the crossing and turning back. The automatic reset is executed either on the next train approaching or after a pre-configured time period.

Axle counters provide a fixed point at which the crossing will be activated. This has an advantage that minimum warning times are assured providing trains are running within the line speed, however the slower the train is travelling the longer the warning time. In comparison, the LCWS calculates the crossing activation time based on the train sound signature and pre-configured minimum warning time. This should result in more consistent warning times for trains travelling at different speeds.
Axle counters are restricted to detecting vehicles whose wheels meet the certain specifications (size, material and speed) and wheels outside these specifications can cause axle counter faults or may not be recorded or detected. In comparison, the LCWS is not limited by the types and speed of vehicle wheels.

If the up and down line speeds on the same track are different then the approach axle counter sections can be made different lengths on the up and down side to provide more consistent warning times. In comparison, the LCWS requires the up and down line speeds to be similar to ensure consistent warning times.

6.3. Predictors

Level crossing predictors, such as ElectroLogIXS XP4, are not designed to be applied in traction return tracks, the two main reasons being:

- Low impedance bond resistance in the approach, which skews linearity for prediction.
- Sporadic traction return voltage levels rising above the equipment designed voltage thresholds on the transmitter and receiver, which can cause electrical damage.

In comparison, the LCWS does not have such limitations. Refer to section 4.2.

To provide safe operation, level crossing predictors are designed to meet the AREMA requirements to detect a rolling track shunt of 0.06 ohms within approach track limits and a stationary track shunt of 0.06 ohms within the island limits. This can cause problems on lines with low traffic or where non-freight locomotive commuter trains are running, due to contamination building up on the rails. In comparison, the LCWS does not have any dependency on track shunt levels or normal rail contamination.

If the up and down line speeds on the same track are different then the approach shunts can be set at different distances on the up and down side to provide more consistent warning times. In comparison, the LCWS requires the up and down line speeds to be similar to ensure consistent warning times.
7. RAMS

7.1. Reliability

Based on an estimated hazard rate of 1.31E-09 per hour for failure modes that result in down time in fail-safe Dark Mode, the calculated MTBF for the LCWS is 765,000,000 hours [7]. This is based on a redundant configuration with two Control Units, each with two sensors in series. This MTBF figure excludes external equipment such as AC power supply, warning lamps and bells.

While in use at client sites since February 2013, WTS have gathered statistics for trains passing the sensors more than 327,000 times up to October 2014. During the operations, there have been some sensor failures caused by deviations from the sensor production procedures and two failures caused by component fatigue. These failures have been accounted for in the design of the upgraded version of the sensor. The component type that caused two sensor failures due to fatigue is not part of the new design, and several other components have been eliminated. As a result the upgraded version of the sensor is assessed to be more robust than the previous version. The upgraded sensor is part of LCWS version 1.3.

7.1.1. Failure Modes

The LCWS Main Assembly has four components in the Signal Board that may cause a breach of an LCWS safety critical function [12]. The worst case failure effect is that the white light (system operating) is permanently on even when the system is down. The failure rate is estimated at 3.16E-08 per hour, which is well below the THR for SIL2 systems (1E-06).

During UK field trials there occurred several times the loss of GSM contact to the LCWS due to problems with the MOXA component. The loss of GSM contact to a LCWS site is not a safety critical failure and does not influence the LCWS safety or performance. However this failure mode impairs the maintainability of the LCWS. It is not a permanent failure of the component and the remedy is to manually reset it.

The sensor unit failure modes from components with the lowest MBTFs all result in fail-safe Dark Mode. These failures are caused by:

- Crystal oscillator manufacturing fault, resulting in sensor failure.
- Bypass capacitor overheating, resulting in sensor detecting more noise or stops working.

As there are two sensors connected to each rail, if any single sensor fails, the LCWS will continue to operate as normal. If two sensors for the same Control Unit fail, then again the system will operate normally. If two sensors on different rails fail the LCWS is unable to operate and will enter fail-safe Dark Mode and automatically issue a message to inform the maintenance team.
### 7.2. Availability

The calculated availability for the LCWS is 99.9999969%, based on an estimated hazard rate of 1.31E-09 per hour and an MTTR of 24 hours. The hazard rate is calculated for failure modes that result in down time in fail-safe Dark Mode. The MTTR of 24 hours includes allowance for maintenance logistics, diagnosis and repair.

The availability performance of the LCWS Main Assembly is expected to be reduced whenever used in areas of high temperatures, where the ambient temperature exceeds 35°C to 40°C [17]. All components have tolerances at least fulfilling -40°C to +65°C. Where possible to deduce, the components have displayed an increase in hazard rate of a factor of two to three at 80°C. However, sensitivity evaluations indicate that the hazard rates would need to increase by between one and two orders of magnitude in order for the LCWS not to meet its availability requirement of 99.996%, excluding planned maintenance, ref [18] section 7.1.3. This availability requirement originates from Jernbaneverket Norway and Network Rail UK, with the latter requiring the higher figure.

The risk assessment and FMECA reports for LCWS version 1.3 provide evidence for operation at higher temperatures. This will need to be confirmed by the imminent ISA report for LCWS version 1.3.

### 7.3. Maintainability

Each LCWS is currently maintained by WTS or a WTS Certified Partner. A WTS Certified Partner may also carry out the installation. MTM can become a certified partner of WTS to perform activities such as:

- Installation
- Maintenance
- Monitoring of level crossings
- Refit sensors and systems
- Configure parameters, for example, change the warning time to match a change in line speed. Parameters that affect the core LCWS software cannot be changed by maintainers.

The above activities can be performed by MTM staff who have completed competency based training provided by WTS.

Software maintenance such as patches, upgrades or other changes can be done remotely.

If an internal malfunction or failure is detected, then the MTM maintainer or WTS Certified Partner is immediately informed by the system as an error reported via a built-in GSM module, which sends an email or optionally forwarded as an SMS message. The maintainer or WTS Certified Partner will then visit the level crossing site and change or replace any faulty components.

LCWS requires GSM reception in the area. The GSM signal is used by LCWS to issue alerts and notices for failsafe conditions, and other maintenance and repair tasks.

The Control Unit typically requires very little maintenance, however there are a number of checks that should be conducted on an annual basis, such as replacement of batteries.

Sensors that have failed or malfunctioned must be replaced with complete new sensors and cables, a procedure that takes 30 to 60 minutes.
7.4. Safety

In case of system failure, or if the sounds detected by the sensors are providing contradicting data, the LCWS is designed to go into a fail-safe state.

An ISA certificate [8] has been issued by Lloyd’s Register Consulting, which assess the LCWS version 1.3 as a SIL2 system for single track level crossings. The ISA report for LCWS version 1.3 is due in August/September 2015.

The safety case [17] covers analysis of the most significant hazards (i.e. the hazards with the potential to impair the LCWS safety critical function) show that the LCWS system has Hazard Rates below the tolerable hazard rate (THR) of $< 1 \times 10^{-6}$ per hour per safety critical function applicable for SIL2.

These hazards, which potentially can lead to an intolerable situation where the system either does not detect or does not warn that a train is approaching the level crossing, are:

- No strike in when train is approaching – due to hardware failure in the signal unit of the main assembly.
- No strike in when train is approaching – due to software not being able to detect a train.
- Side switch and extinguishing of the light before the train has traversed the level crossing.

The worst case failure effect is that the white light is permanently on when the LCWS system is in Dark Mode. However, analysis has proven that the failure rate is well below the THR for a SIL1 system.

The ISA report for LCWS version 1.3 is due in August/September 2015. In the meantime, as a guide to the validation of the LCWS, the ISA report for LCWS version 1.2 [9] concludes:

- The software requirements are in general found to be adequate, and the software specifications are in general found to be adequately covering the software requirements.
- The LCWS software has no known deficiencies, however, the LCWS with its software has some limitations of use, refer to section 5.
- WTS has confidence in the selected external tools as they are proven in use world-wide and during the development of the LCWS software.
- The LCWS Main Assembly, covering the LCWS Control Unit, Signal Unit and Power Supply Unit, has been found to pass the relevant validation criteria and the relevant system requirements.
- The LCWS Sensor Unit has been found to pass all the relevant validation criteria and the relevant system requirements.

WTS is currently not certified according to ISO 9001. As one of the requirements of SIL1 certification is to be either ISO 9001 certified or have an in-house quality system compatible with the relevant parts of ISO 9001, Lloyds has made an audit of the WTS quality system as part of the overall assessment. The audit resulted in 3 non-conformities and 2 observations, for which WTS has presented a plan for handling these con-conformities and observations.

WTS confirm that MTM can contact Roar Andreassen at Lloyds Register on either +47 47 02 48 78 or by roar.andreassen@lr.org
7.4.1. Safety Related Application Conditions

The safety case [17] contains a number of Safety Related Application Conditions (SRACs), of which the following will have an impact on configuration, installation, operation and disposal of the LCWS.

- There is a hazard that the LCWS does not send logs due to power fault, faulty GSM component or GSM coverage. This can result in maintainers being unaware of the system status and whether the system is working. Missed reports should trigger an alarm in the monitoring system and maintenance personnel should be sent to the site.

- There is a hazard of damage to the LCWS sensors due to maintenance work being done while the LCWS has not been shut down. Damaged sensors can result in safe Dark Mode, reduced warning or no warning. Maintenance procedures should specify that the LCWS should be shut down during maintenance activities.

- There is a hazard that if warning times are too long, users may ignore the warning. Consideration should be given to variation in rolling stock, train speed, track quality, crossing proximity to stations and trains slowing down during site specific safety case, configuration and commissioning.

- There is a hazard that if warning times are too short, users may not be able to cross before the train arrives. Consideration should be given to variation in rolling stock, train speed and track quality during site specific safety case, configuration and commissioning.

- Extreme weather (snow): Not relevant to MTM rail network.

Lloyd’s have included an additional SRAC from the independent safety assessment:

- A prerequisite for using the LCWS version 1.3 as a SIL2 system is that the level crossing is equipped with a signal that can indicate that the LCWS is in operational state.
7.4.2. Risk Analysis

WTS have conducted a risk analysis [7] for the LCWS as part of the process mandated by EN 50126 [23]. The risk assessment is aimed at LCWS version 1.3, which has been successfully independently assessed for SIL2.

The analysis identified no intolerable risks, however a number of hazards leading to undesirable level risks were identified, including:

- No strike in when train is approaching.
- Deactivation of warning before the train has traversed the crossing, due to saturation of piezo elements or periodic signals from sensors e.g. noise containing pure tones.
- Short warning times, due to variation in rolling stock, train speed and rail quality.
- Long warning times, due to variations in rolling stock, train speeds, track quality, level crossing too close to a station, trains slowing down.
- Fault current effects, hardware failure or train operation (e.g. train stopping for more than 300 sec after strike in), resulting in Dark Mode.
- LCWS not being shut down during maintenance work, resulting in sensor damage.
- LCWS triggered by noise not at the crossing, e.g. from braking trains, stations and curves
- Packed snow or ice along the rails reducing the sound conductivity and warning times
- Loss of system redundancy due to component failure.
- Component failure causes AC mains failure, resulting in battery mode followed by shut-down.

The risk assessment concludes that the hazards identified are all within the THR for SIL2. The assessment also recommends follow up actions including a new system requirement to avoid long warning times and risk reducing measures for the medium risk hazards, with the objective of taking LCWS to SIL3. Refer to section 12 regarding SIL3.
8. Environment

Field tests at client sites have been performed since 2013, and is on-going, covering diverse climatic conditions from the Australian Pilbara region to the cold climate of Grong in Norway.

Environmental tests, including vibration, temperature and water tightness, are conducted using the requirements of EN 50125-3:2003 [25] as the target. WTS have recorded the results of validation against environmental requirements in a set of validation reports [27], [28], [29]. These reports show the LCWS passed environmental tests for temperature, vibration and sensor ingress protection.

Following field trials, a number of failures related to vibration have been analysed and rectified for LCWS from version 1.2, see [26] section 4.

The sensors are rated to IP67. The Main Assembly would need to be housed in a location case that meets the VRIOGS IP rating for trackside B4 class equipment housings.

The LCWS Safety Case [17] states that LCWS version 1.3 Main Assembly components have tolerances at least fulfilling -40°C to +65°C. The LCWS Sensor Units consist of components that are resistant to temperatures from -40°C to at least +80°C, however, the availability performance of the Sensor Unit is expected to reduce at higher temperatures.

LCWS failure rate calculations have been done for temperatures of -40°C, 25°C and 80°C, which show the reliability and availability is within the required levels, and the safety hazard rates are within the level for SIL2.

8.1. Electromagnetic Interference and Compatibility

The LCWS is designed not to emit electromagnetic radiation and to withstand electromagnetic radiation as might be experienced by the rail lines. Therefore, no particular precautions are deemed necessary providing that the instructions for installation, operation and maintenance are followed.

The LCWS has been independently laboratory tested by Nemko, Norway, against the CENELEC EMC standard EN50121-4 [24]. The LCWS passed all EMC tests, once a number of equipment modifications were made to decrease spurious emission in the 30-1000 MHz range.
Network Rail have stated from their own testing that there is no galvanic or EMC interaction between the LCWS and the signalling systems or other infrastructure [17].

8.2. Hazardous Substances

The LCWS has been designed and manufactured in accordance with the requirements of ROHS Directive 2011/65/EU Article 4. As such it complies with the European limits on restricted substances and their maximum concentrations.
9. **In service use**

WTS have a commissioned LCWS site in the UK, and a number of installed trial sites in UK (Anglia region), Norway, and South Africa. These installation are for LCWS up to version 1.1.

The first WTS LCWS commissioned in the UK was for Network Rail (NR) at Whitehouse / Priory View crossing on the Cromer to Sheringham line on 29 Jan 2014, refer [20] and [22]. The commissioning has been conducted on a single line crossing, with no requirement for extending the activation time for a second train approaching the crossing (equivalent function to holding sections on a traditional crossing). A subsequent trial phase is for an installation with multiple lines with provision for extending the activation time for a second train approaching the crossing. This phase of the trial is still ongoing, with WTS currently awaiting the national certificate from NR.

NR are continuing to acquire LCWS equipment for future in-service use in the Anglia region. To date, WTS have provided 108 systems to NR, of which 50 have been installed and 13 of these are powered up. Of the installed sites, 8 are sending data (as GSM messages) and 4 of these are being officially recorded.

In Australia, an LCWS has been installed for Rio Tinto in the Pilbara. This system is currently powered down due to re-railing of the tracks at the site. In reference this site, WTS have confirmed that Tony Godber at Rio Tinto has agreed to be contacted by MTM in relation to the LCWS.

10. **Site Configuration, Installation and Testing**

10.1. **Configuration**

Excluding the normal physical installation requirements such as the location of Main Assembly housing, sensors, cable routes, power and warning lights/bells, the LCWS only requires the setting of three configuration parameters. These configuration parameters, sensitivity threshold, limiter setting and auto-reset, are described in the commissioning section 10.4.

10.2. **Installation**

WTS have an installation manual [4], which covers the installation of the Main Assemblies and Sensors, including ground works, pedestal mounting and connection of power and warning lights. The manual also covers initial start-up and software installation.

The Sensor Units are installed directly on the rails underneath the railhead. The sensors have integrated magnets that attach to the rails. In addition to this the sensors are glued to the rails after the rail attachment area has been cleaned of rust, grease and other contaminants. There are four sensors per track, where two sensors are placed on the same rail 5m apart. Cables are run from each sensor to the Main Assembly housing.

Based on installations by Network Rail staff trained by WTS, a typical installation for either single or double line can be achieved by a 3 person crew in under 8 hours without interference to operations.

10.3. **Testing**

WTS have a test specification [14] that is applicable to a typical single or double track installation. This test specification would be a suitable base for test plans for any potential site trial on the MTM network.
10.4. Commissioning

The WTS commissioning manual for LCWS [13] contains a set of commissioning tests to confirm the fail-safe operation. The tests include disconnecting sensors, disconnecting warning lights and loss of power to a Control Unit. The expected email error codes are also stated.

Part of the commissioning is to tune the LCWS for the following three parameters:

- Sensitivity threshold, which controls the warning time given by LCWS. For a continuously welded rail the dampening of sound in the rail is roughly 50 dB/km. Therefore, setting this threshold to -50 dB will result in the warning activated when the train has approached to within 1 km of the level crossing. Depending on the line speed, this will control the warning time.

- Suppression of braking trains. This setting, referred to as the limiter setting, depends on the average speed of trains approaching the level crossing and the amount that sound is dampened per metre by the rails. The formula used is: Limiter setting = average speed (m/s) * sound dampening (dB/m).

- Automatic reset to recover from Dark Mode. The LCWS can be configured to execute an automatic reset either on the next train approaching or after a selected time period.

11. Training

WTS can and does provide all types of training, including LCWS configuration, installation and maintenance.

12. Future Improvements

The road map of future improvements and upgrades based upon clients outside Australia and the results received will be provided to MTM as they become available.

The LCWS software version 1.2 assessed by the ISA [9] complied with all requirements except for two requirements:

- The system should be able to do an automatic reset when needed, which corresponds to the “auto-reset” feature

- The system shall be able to initiate a different warning signal when a second train is approaching shortly after the first train, which corresponds to the “another train coming” feature.

These two requirements should be satisfied by LCWS version 1.3, however this will be confirmed when the ISA Report for version 1.3 becomes available in August/September 2015.

LCWS has been installed under trial at three sites in the UK where there is double track. LCWS version 1.3 has been certified by ISA for single track level crossings and would require further ISA certification to be commissioned for double track crossings.

Certification of LCWS to SIL3 in the future is dependent on customer needs and the additional cost for WTS to obtain SIL3. No date has yet been set for this activity.
13. Conclusions

The LCWS has been designed and developed under a regime that complies with the CENELEC standards for railway applications. This has allowed LCWS to obtain SIL2 certification from an ISA for single track crossings.

The use of sound detecting sensors has some significant advantages over the use of traditional track circuits and also axle counters. The main advantage over predictors it that LCWS can be used in a traction return environment.

WTS have field tested the LCWS by trials in the UK, Norway, Australia and South Africa, and commissioned in-service use at a site in the UK. WTS also have mature installation, commissioning and maintenance manuals, which can be used as the basis for ARO documentation to support the installation and in-service use.

LCWS has been tested to validate the system against CENELEC standards for RAMS and environmental requirements. Some environmental requirements would require assessment of LCWS for the MTM railway environment, including humidity, condensation, chemical/corrosive resistance, and for the sensors, solar radiation and fire resistance.

Based on a review of the WTS documentation, there should be no technical impediments to trialling the LCWS on a single track crossing in the MTM rail network, providing that the implementers are cognisant of the documented LCWS limitations.

To be considered for use in the wider MTM rail network, the LCWS would require field test results (from Australia or overseas) and ISA certification for multi-track level crossings. Field trials would be recommended on the MTM rail network to confirm there are no compatibility issues with the 1500V DC traction environment.
14. References

[13] Level Crossing Warning System Commissioning Instructions, Rev 2.0, 26 Feb 2015
[14] Level Crossing Warning System Field Test specification, Rev 2.0, 7 Apr 2015
[16] LCWS System Definition and Application Conditions, Rev 3.0, 14 Apr 2015
[21] Certificate of Acceptance for Safety Cases applicable to Network Rail, Jan 2014
[23] EN 50126. Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)