Institution of Mechanical Engineers

Railway Challenge

Technical Specification

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1 Requirements

1.1 General

1.1.1 Design

Detail drawings. Full performance calculations. Structural calculations. Parts lists

1.1.2 Safety / Failure Analysis

Top down analysis. Bottom up analysis (Clauses 3.1, 3.2 refer)

1.1.3 Manufacture

Procurement. Manufacture. Assembly

1.1.4 Testing

Recorded on-site validation of all performance calculations / statements (Clause C12 of the Railway Challenge Rules refers). Off-site comparative demonstration (Clause 10 refers) of specified performance characteristics

1.1.5 As-Constructed Drawings

Detailed drawings updated to reflect post-assembly modifications with full demonstrable version control

1.1.6 Spares / Tools / Test Equipment

Procurement, design, manufacture, assembly of spares, tools and test equipment

1.1.7 Options

Optional requirements are identified with the following symbol: ★. Note that at least one must be delivered (Clause B2.2 of the Railway Challenge Rules refers)

1.2 Cost Benefit Analysis

1.2.1 Production

Production cost estimate against the selected design and method of manufacture (on the basis that the initial locomotive is a prototype for a production run) of 50 units

1.2.2 Testing

Cost of any testing, identified as required and above and beyond the selection testing of the prototype as referred to in Clause 10 of this document

1.2.3 Maintenance

Maintenance cost estimate, including cost of all spares / consumables (Clause C12 of the

Railway Challenge Rules refers)

2 System Description

2.1 Configuration

The wheel arrangement and general configuration of the locomotive shall be at the Team's discretion, subject to the conditions herein

2.2 Operation

The locomotive shall be able to operate remotely via radio-based or cable-based transmission. All functions shall be operable via the remote system. Specified functions shall be operable only via the remote system

Such remote systems shall be designed on the basis that the operator will be located within the trailing load as described in Clause 10.1 (supplied by a separate party)

2.3 Design - Aesthetic

It is not intended that the locomotive be a scale representation of a larger vehicle

The aesthetics of the locomotive, however, with respect to proportion, contours and colour should be considered important, reflecting the need to stand out against a notable number of competitors in the market

3 Systems Assurance

3.1 Top Down Analysis - Safety

The Team shall produce and provide a comprehensive top down safety analysis, the exact nature of which shall be as selected by the Team. The analysis shall include a text comprising conclusions with appropriate justification for acceptability

The analysis shall identify all potential safety related failures and via appropriate statistical analysis demonstrate that the probability pre and post mitigation is understood, and that post-mitigation risk levels are As Low As Reasonably Practical (ALARP). The analysis shall include a text comprising conclusions with appropriate justification for acceptability

3.2 Bottom Up Analysis – Safety

The Team shall produce and provide comprehensive bottom up safety analysis, the exact nature of which shall be as selected by the Team

The analysis shall identify all safety related consequences of single component failure, for all components and, via appropriate statistical analysis, demonstrate that the likelihood and

severity of consequence pre and post mitigation is understood, and that post-mitigation levels are ALARP

The analysis shall reflect its conclusions, and document such reflection, in any proposal to re-use components shown to have high safety criticality

3.3 Maintainability

The Team shall demonstrate that all components replaced as part of a planned preventative maintenance programme (Clause C12 of the Railway Challenge Rules refers) can be replaced without disruption to any other component other than designated access facilities and the immediate connection to interfacing components

The design shall consider hazards associated with maintenance and repair activity when undertaking the production of the analysis specified in Clauses 3.1 and 3.2. These should include, but not be limited to, electric shock, hazardous substances, entrapment, sharp edges and burns

All connectors (wire, hose, pipework) shall be marked to show identity

3.4 Reliability

The Team shall demonstrate that the completed prototype locomotive is adequately reliable for the purposes of undertaking the selection testing of the prototype as referred to in Clause 10 of this document by undertaking test-running. This shall comprise no fewer than four (cumulative) hours of operation, during which all functions detailed in the selection testing shall be exercised. Test-running shall take into account the track characteristics as described in Clause 4.7, and in particular those relating to curvature

In all cases the final hour shall be of near continuous operation without any failure inhibiting movement

The completion of reliability testing as described in this clause must be verified by a Chartered Engineer and evidenced by provision of a video showing the locomotive in normal operation during the testing specified in this clause. The video shall include at least 20 minutes of the final hour of running

The video shall include demonstration of the intended jacking process, as described in Clause 6.4.2

The video shall be made available to the Railway Challenge organising committee via any selected method at least two weeks before the Railway Challenge competition weekend. Failure to do so will incur a penalty

4 Technical Requirements – General

4.1 General

The locomotive shall provide self-contained motive power and be able to operate for 3 hours without refuelling, on the basis that operation comprises continuous travel at 5km/h on a 2% gradient with a 400 kg trailing load of negligible friction[12]. All functionality shall remain available for repeated use throughout this period without any further input. The locomotive shall be able to haul and start a trailing load of up to 1800 kg on a 2% gradient

The type of motive power utilised is entirely at the discretion of the team, subject to the other requirements of this specification

Refuelling from zero to 100% capacity shall take no longer than 120 seconds. If refuelling comprises the replacement of energy storage assets, no individual such asset shall have a mass greater than 25 kg[3]. Each asset must be labelled to state its mass

All energy storage devices must be appropriately protected and secured

4.2 Materials

4.2.1 Inventory

The Team shall provide a full inventory of materials (or BOM: Bill of Materials) used in the construction of the locomotive, for all materials making up more than 5% of the total mass

4.2.2 Safety

The Team shall demonstrate (as part of the delivery of the requirements specified in Clauses 3.1 and 3.2) that the selection of materials takes safety implications, including fire, duly into account

4.2.3 Environmental

The Team shall demonstrate that 95% of components by mass can be disposed of in such a way that facilitates recycling

No hardwood components shall be used for which Forest Stewardship Council (FSC) certification cannot be demonstrated

4.3 Loading Gauge

The locomotive shall be designed to operate within a dynamic loading gauge as described in Drawing RC02

Gauge infringement resulting from component failure (including inadvertent opening of access panels) or movement during operation must be included with the top down and

[1] Note that these figures define energy capacity only and not maximum performance / environment
[2] Note the requirements of the Railway Challenge Rules (Clause C12). For this requirement, the compliance statement should comprise operation endurance calculations
[3] If refueling comprises the replacement of energy storage assets then the specified maximum refueling time will be demonstrated during scrutineering

bottom up analyses (Clauses 3.1 and 3.2 refer)[4]

4.4 Mass

4.4.1 Total

The total mass of the locomotive shall not exceed 2000 kg. Due consideration shall be taken of all traction and braking requirements

4.4.2 Axle Load

The maximum axle load of the locomotive shall be 500 kg

4.5 Operating Conditions

With respect to cooling systems and motor rating, the locomotive shall be designed for continuous operation in operating conditions as follows:

- The locomotive shall be designed to operate in direct sunlight, and under all forms of precipitation (without temporary protection measures)
- The locomotive shall be designed to operate at shade temperatures between -10 and +40 degrees centigrade and between 0 and 90% humidity levels

4.6 Track Characteristics

The locomotive shall be designed to operate on track at its maximum speed (Clause 5.1 refers) with the following characteristics:

- Gauge: 10 ¼ inches (between rail inner faces). May widen to up to 10 ½ inches on curves
- Minimum horizontal curvature radius: 18m
- Maximum track twist gradient: 6mm over 0.25m
- Maximum gradient: 1:84
- Wheelsets shall comply with all characteristics detailed in Drawing RC04
- Minimum wheel diameter: 200mm

The Team shall demonstrate that all the above clauses have been duly considered in the design, when operated as described in this document

The team shall consider weight distribution in the analysis. Such consideration shall include the impact of any change in centre of gravity caused by an on-board operator (in the

[4] Due attention should be paid at an early design stage to guarding, with respect to protection against injury / entrapment by moving parts, chains and belts. Out of gauge, insecure or flexible guarding will prohibit locomotive operation in the Railway Challenge

relevant locomotive module if the locomotive comprises multiple parts) should the relevant option be exercised (Clause 6.3 refers)

4.7 Markings

The locomotive shall be painted or otherwise protected against all specified environmental factors as specified in Clause 4.6 in a manner to be selected by the Team, but not in a manner resulting in non-compliance with any other Clause of this document

The Team shall ensure that markings included in any scheme, where feasible, highlight the presence of any hazards and warn of the presence of the locomotive itself

4.8 Aerodynamics (Option)★

The locomotive design shall duly consider energy loss arising from air-resistance and, notwithstanding other requirements, minimise such losses

The Team shall undertake CFD analysis and / or measurements on the actual locomotive, or a model demonstrated to be representative, to ascertain air-resistance at a constant 50 km/h (Clause C8 of the Railway Challenge Rules refers)

5 Technical Requirements – Performance / Control

5.1 Operating Speed

The locomotive shall be limited to a maximum speed of 15 km/h. The locomotive shall incorporate speed limiter systems to prevent operation above this limit

The locomotive shall be designed so that it may be towed, when on track with characteristics as described in Clause 4.7, at a speed up to 15 km/h. The design of the traction system shall be such that it is not damaged whilst being towed at this speed

5.2 Energy Recovery

The locomotive shall incorporate an energy recovery system for use in retarding the locomotive and trailing load. Energy so recovered may be stored within the energy storage system supplying the primary traction system provided the Team is confident with respect to compliance with requirements of Clause 5.7.1 (Bullet 5) and Footnote 8. The retardation rate delivered by the energy recovery system shall be limited to a maximum deceleration rate of 1.3 m/s/s on level track (assuming no trailing load)

The locomotive shall utilise recovered energy only, if selected by the operator, to deliver tractive effort

The performance of the locomotive with respect to the energy recovery will form a major part of the test specification referred to in Clause 10.1

Particular attention shall be paid to the requirements of Clauses 3.1 and 3.2 with respect to stored energy systems

5.3 Braking Systems

In addition to the energy recovery system, the locomotive shall incorporate the following exclusive braking systems:

- A service brake
- An emergency mechanical brake, which shall operate indefinitely even in the event no power is available. This will provide acceptable parking brake functionality, and no separate system is mandated

Both above services may be provided by a common actuator

5.4 Braking Performance[5]

- All brake systems shall be limited to a maximum deceleration rate of 1.3 m/s/s (+0/-0.15) on level track (assuming no trailing load)
- The emergency brake shall provide a deceleration rate of 1.3 m/s/s (+0/-0.15) on level track (assuming no trailing load)
- The emergency brake shall operate whenever communication with the remote control unit is lost, regardless of current locomotive operating state, within 0.5 seconds of disconnection
- The emergency brake shall operate in the event that service brakes are released but the presence of an operator in contact with the remote control unit is not detected for a period longer than 0.5 seconds
- The locomotive (or remote control unit if wired to the locomotive) shall be fitted with a tether point and tether plug linked (via a cord of 2m length if wired to the locomotive, 0.5m if wired to the remote control unit) to a wrist band, so that separation of the operator and locomotive is detected. The emergency brake shall operate in the event of such separation within 0.5 seconds. The wrist band must be worn by the operator at all times that the locomotive is powered. This function shall be directly electrically or mechanically facilitated and not dependent on software
- The remote control unit shall incorporate an emergency stop button which shall operate the emergency brake, regardless of current locomotive operating state, within 0.25 seconds. The remote control unit shall include a second emergency stop button on a flying lead accessible to the riding judge
- An emergency brake button, clearly marked and safely accessible, shall be provided on both sides of the locomotive which shall operate the emergency brake, regardless of current locomotive operating state, within 0.25 seconds. This function shall be directly electrically or mechanically facilitated and not dependent on

[5] Note the requirements of Clause C12 of the Railway Challenge Rules (compliance matrix)

software[6]

- The emergency brake system shall feature a manual brake release to enable movement of the locomotive by external means when it is safe to do so. The emergency brake release system must be such that inadvertent operation is impossible, and emergency brake isolation is inherently visible to all parties. Release shall be, preferably, via continuous attended operation. Manual re-application of the brakes following release shall also be possible

- The brake systems on the locomotive shall be so designed that no single fault shall reduce the available brake effort by more than 50%.

- Operation of the emergency brake by any means shall set the traction rate to zero. Release of the emergency brake button shall have no effect unless full service braking is selected on the locomotive controller

5.5 Braking Control – Automatic

The locomotive braking system shall incorporate an automatic braking mode which shall, if selected, bring the locomotive and trailing load to a standstill, exactly 25m after passing a single lineside distance marker[7]. No tractive effort shall be applied in this mode and the brakes shall remain activated. Operation in this mode will be indicated (clause 5.7.1 refers). All other braking systems shall remain normally operative when this mode is selected

5.6 Traction Control

Traction control shall provide continuously variable or multi-stepped tractive effort, at the Team's discretion

5.7 Indications

5.7.1 Control

Clear and continuously visible indications shall be provided to:

a) the locomotive operator and

b) the Challenge judge riding on the trailing coach,

via the same or separate means, to be selected by the Team, of the locomotive's functional status. These shall include, but are not limited to:

- Braking system fault

[6] Underlined text indicates requirements against which non-compliance is likely to result in the locomotive not being permitted to run

[7] Teams will be expected to provide and temporarily fix a single detectable location device of their choice at the location of this marker. This device will be designed such that it is entirely outside the structure gauge limits (Drawing RC02 refers). Such devices may be located between the running rails provided gauge compliance is met

- Tractive effort applied
- Brakes applied
- Fuel or charge level (main storage) (continuous)
- Status of recovered energy storage (continuous)
- Locomotive speed (in all locations, including tunnels)
- Locomotive running on recovered energy only (Clause 5.2 refers)
- Automatic braking mode selected
- Auto-coupler coupled/uncoupled status (where this facility is provided – Clause 6.2.2 refers)

The design of all such indication shall allow for the stated environmental conditions (Clause 4.6 refers)[8]

5.7.2 Safety

The following indications shall be displayed by the locomotive, visible without obstruction to persons in front of or behind the locomotive

- One or more white lights on the leading end of the locomotive so as to indicate the selected direction of travel
- One or more red lights on the trailing end of the locomotive so as to indicate the selected direction of travel
- One or more yellow (not amber / orange) lights (visible from all horizontal directions) to indicate (when lit) that the locomotive is live and capable of movement via application of traction or brake release, either deliberately or via control system fault
- Fire, by means to be selected by the Team

All safety related lighting shall deliver between 200 and 1000 lumens. Directional lighting need only operate if powered motion functions are active

5.8 Audible Warning

A horn or whistle shall be fitted to the locomotive which shall be operable from the remote control unit. The maximum C weighted sound pressure level ($L_{pCeq,T}$) at 1m distance (between 0.5m and 1.5m above ground level) shall be no less than 96dB and no greater

[8] Note that visibility will be assessed as part of scrutinising, which will be undertaken on a moving vehicle, possibly in bright sunlight. The scrutinising team may recommend disqualification from one or more challenges should visibility be deemed inadequate

than 112dB. The principal frequency of the audible warning device shall be between 800Hz and 3570Hz. The sound shall be continuous and not intermediate

5.9 Location Announcement (Option)★

A system shall be provided that automatically provides, audibly and visually and to all occupants of trailing vehicles, location information, which shall include:

1. Lineside features of interest (Railway Challenge Rule Clause C10.5 refers) within 1 second of passing
2. Location when at planned stops (Railway Challenge Rule Clause C10.5 refers) within 1 second of stopping

Teams may select any available technology, including trackside devices, to determine when to provide the announcements.

Detail of the system shall be included in the Design Report appendix (Clause C10 of the Railway Challenge Rules refers)

Assessment will be as described in the Railway Challenge Rules

5.10 Remote Data Recording (Option)★

The locomotive shall be equipped with a recording and transmitting system for all three control data categories as follows:

1. Operator and control system inputs (including, as a minimum, braking and traction demand)
2. Control system outputs (including, as a minimum, braking and traction demand)
3. System performance and asset response / status (including, as a minimum, speed, time and location)

The recording of all such data shall be made at intervals no greater than 5 seconds

The mandatory indications detailed in Clause 5.7.1, and the status of all items listed above will be displayed live and remotely on a laptop or other device and logged at the recording intervals, including timestamps, with the option to display such data on the remote device in tabular or graphical format. During the competition weekend, the laptop or other device will be located in the marquee adjacent to the station and shall provide the means to be connected to a projector

Detail of the system shall be included in the Design Report appendix (Clause C11 of the Railway Challenge Rules refers)

Assessment will be as described in the Railway Challenge Rules

5.11 EMC (Electromagnetic Compatibility)

Teams are required to demonstrate in their design report how any RF (radio frequency) systems in use comply with local regulations, including EIRP (Equivalent Isotropic Radiated Power) and duty cycle limits

5.12 Operational Readiness

The locomotive, if complete / assembled, shall be capable of full operation as described within this document in no more than three minutes from any control state

6 Technical Requirements - Locomotive Structure

6.1 Structure

6.1.1 Calculations

The Team shall provide analysis and calculations to demonstrate the adequacy of structure which shall include / allow for the following (on all track conditions detailed in Clause 4.7):

- A 30% dynamic loading factor (factor to be applied to all loads in structural analysis to allow for sudden application)
- Tensile and compressive loads applied to coupler bars and fixings (Clause 6.2 refers) at both ends, demonstrated by the Team to be appropriate
- Loads resulting from use of jacking / lifting loads at the jacking / lifting points provided by the Team (bogies and / or wheelsets to remain attached)

6.2 Coupler

6.2.1 General

On each headstock of the locomotive a coupling shall be provided as follows:

- A ‘U’ bracket with centreline 10” above rail head supporting a vertical shaft or pin of ¾” diameter with suitable retention

A single coupler bar shall be provided, with one end suitable for the shaft as referred to above, and a hole to clear a coupler pin of ¾” diameter at the other

The coupler bar design (including length) shall be assessed against the track characteristics, haulage and braking loads as specified in this document, taking into due account the end-throw of the locomotive and all limits of dynamic displacement. In the event the design proves impractical, the general arrangement of the locomotive shall be changed

Drawing RC05 shows a typical design for a coupler bar (subject to the assessments above)

6.2.2 Auto-Coupling Facility (Option)★

The locomotive shall be provided with an auto-coupler facility, which will be credited as described in the Railway Challenge Rules (Clause C7 therein refers). This shall meet the performance requirements for competing in the Auto-Coupler Challenge

The locomotive shall at one or both ends be fitted with a means by which safe and secure connection to a vehicle with a coupling 'U' bracket (or box bracket[9])(Clause 6.2.1 refers) can be undertaken without the manual handing of any item located between the two vehicles

Control for coupling and uncoupling shall be by the remote control unit. The control unit shall indicate its status to the operator via indication on the remote control unit (Clause 5.7.1 refers)

The configuration and design of such an auto-coupler will be the Team's discretion. Teams may also elect to provide a mating half or other coupler interface on the coupling 'U' bracket of the vehicle being coupled to.

The design of the auto-coupler will tolerate a height above rail head of the connecting vehicle's coupler from the specified height (Clause 6.2.1 refers), -2" / +3". The height of the auto-coupler on the team's locomotive may be set manually prior to the start of the auto-coupler challenge. There is no requirement for a remote height adjustment although the auto-coupler system may provide for some self-alignment of the couplers during engagement

The auto-coupler system shall enable the consist to safely negotiate track with the characteristics detailed in section 4.7 of the Technical Specification noting that the coupling and uncoupling process will take place on nominally straight track. This shall include capability to take the necessary draw and buff loads as required in the Auto-Coupler challenge based on the team's foreseen acceleration and deceleration (braking) rates

The auto-coupler facility shall permit the safe use of the coupler bar (Clause 6.2.1 refers) or be removable such that the coupler bar may be alternatively used

Detail of the system shall be included in the Design Report appendix (Clause C7 of the Railway Challenge Rules refers)

Assessment will be as described in the Railway Challenge Rules

6.3 On-Board Operator (Option)★

6.3.1 General

In addition to control by an operator in a trailing vehicle, the locomotive shall incorporate accommodation for an on-board operator. The on-board operator shall have adequate visibility for safe movement in one or both directions (Teams may elect to provide full symmetrical bi-directional control, or rear-view facilities only for limited reverse movement). Refer to Clause C9 of the Railway Challenge Rules

6.3.2 Controls

If the locomotive incorporates accommodation for an on-board operator, relevant controls

[9] On some trailing vehicles, applicable to the Auto-Coupler Challenge, a box bracket may be present (effectively a 'U' bracket with sides). This should be considered with respect to the design of the auto-coupler system. Drawing IMECH-MISC-001-B shows an example of a coupling bracket on a trailing coach.

and indications shall be via a permanent integrated control panel (in addition to the specified remote panel), with indications as per Clause 5.7.1. If operation is by an on-board operator, all indications on the remote panel must remain functional, as must its emergency brake button. All controls other than the emergency brake button must be disabled

6.3.3 Operator Detection

If the locomotive incorporates accommodation for an on-board operator, the control system must either continuously, or at a maximum of five second intervals, detect the presence of an aware and conscious operator (for acceptability assessment principles see Clause C9 of the Railway Challenge Rules)

6.3.4 Safety

Teams shall ensure that due consideration is made with regards to on-board operation in the safety analysis prescribed in Clause 3, which shall include as a minimum:

- Ride and risk of derailment with a driver onboard the locomotive (Clause 4.7 refers)
- Risks of injury to the driver including heat, electric shock, shock and vibration, moving parts, and the potential for fire/explosion
- Ensuring suitable containment for the driver, but also providing a means for rapid evacuation as required

6.3.5 Ergonomics

The design of the on-board operator position must cater for person dimensions between 5% female to 80% male without any significant constriction of movement

When in the operating position, no part of any on-board operator shall protrude beyond the permitted loading gauge[10]. Compliance shall be ensured via the creation of two or three dimensional replica human forms (which must be available for static scrutineering)

The static position of the on-board operator must not include any rotation about the vertical axis of any part of the body, or any left/right asymmetry

The on-board operator seat must incorporate back support

6.4 Jacking and Lifting

6.4.1 Jacking wheels for transverse movement

The team shall provide a set of swivel type jacking castors to allow the lifting and transverse movement across hardstanding (approximately level with the railhead, +/- 25mm) for recovery and routine transportation to and from the track. The wheels shall be rubber-tyred (solid or pneumatic) and have a minimum diameter of 150mm. The castors when fitted shall land when lowered no further than 350mm from the adjacent running rail.

[10] For full details see Drawing RC02

Locomotives shall be provided with fitment points for the supplied number of such wheels and shall be designed so that all components (such as bogies and wheelsets) are retained during the use of the jacking wheels.

Fitment and removal of all castors, by two competent persons, shall take no longer than five minutes in total.

Jacking wheels and any accessories or tooling required for jacking shall be stowed on the locomotive when they are not in use in such a way that provides compliance with Clause 4.3.

With jacking wheels fitted, the requirements of Clause 4.3 do not apply.

Jacking wheels are to be considered locomotive components and so shall be included in the bottom up safety analysis described in Clause 3.2.

6.4.2 Jacking or lifting for maintenance

A system for jacking or lifting all or part of the locomotive for the purpose of removing a powered wheelset shall be provided. The system shall be designed on the basis that operation will be in a location where ground level is coincident with railhead level (+/- 25mm).

No part of the system used to jack or lift the locomotive may extend more than 1 metre from the adjacent running rail.

The system shall be designed and assessed to ensure its safe operation and stability[11] at all times such that manual maintenance activities can be performed without unacceptable risk. The system and process shall be subject to a method statement and risk assessment (Section A17 of the Rules refers). The jacks shall be of a design that allows a controlled rate of descent[12].

The jacking wheels (Clause 6.3.1 refers) may also be used as part of the system of jacking or lifting for maintenance subject to also complying with the requirements of this clause.

6.4.3 Jacking Point Marking

The points at which jacks attach to the locomotive shall be clearly indicated by clear inverted-triangle symbols

7 Running Gear

7.1 Vehicle Suspension

[11] The assessment of stability will include the method by which the jacking or lifting device is prevented from moving from the jacking point during operation

[12] Whilst no form of jack is prohibited, teams should note that the pressure release screw on simple bottle jacks cannot be considered to provide controlled descent

7.1.1 General

The vehicle suspension shall provide for safe operation of the vehicle at all specified speeds and avoid the generation of excessive wheel flange forces (esp. forces causing flange climb) during curving. The Team shall provide detailed calculations to confirm that this criterion has been satisfied. Coefficients of friction varying between 0.15 and 0.6 between wheels and rails shall be used.

7.1.2 Wheel Unloading

The Team shall ensure that, when the locomotives operate on track with specified characteristics, the maximum wheel unloading under this condition shall not exceed 60% of the nominal wheel load. The latter is defined as the measured wheel load with the locomotive stationary on straight and level track. The Team shall provide detailed calculations to confirm that this criterion has been satisfied. Coefficients of friction varying between 0.15 and 0.6 between wheels and rails shall be used.

7.1.3 Axlebox Longitudinal Movement

To as great a degree as possible, the Team shall seek to allow, or achieve on an active basis, longitudinal movement of axleboxes so as to achieve stable alignment of wheels tangential with respect to the alignment of the rails

7.1.4 Unsprung Mass

The team shall provide a breakdown of locomotive mass with respect to the proportion unsprung, supported by primary suspension only and supported by primary and secondary suspension

7.2 Earth Bonds

The design of the locomotive shall demonstrate protection against electric shock. In the event any such risk exists, earth bonds shall be provided between one axlebox on each axle and the locomotive underframe and/or all normally accessible metallic structures and enclosures

Designs shall demonstrate due consideration of the following:

- containment of electrical components in suitable cabinets
- bonding paths from all metallic cabinets and other conducting components.
- specification of bonding cables and fasteners

7.3 Transmission

The form of power transmission employed by the locomotive is entirely at the discretion of the team. However, due attention should be paid at an early design stage to guarding, with respect to protection against injury / entrapment by moving parts, chains, and belts. Out of gauge, insecure or flexible guarding will prohibit locomotive operation in the Railway Challenge

8 Technical Requirements - Fire Protection

8.1 General

The locomotive shall be fitted with heat and smoke detection systems which in the event of activation, shall:

- Cause the emergency brake to be operated

- Sound an alarm, as to be selected by the Team, audible to all persons in the first trailing vehicle

- Activate indication to the operator (Clause 5.7.2 refers)

9 Spares, Special Tools and Test Equipment

9.1 Tools / Test Equipment

The Team shall manufacture, or otherwise provide, all tools and test equipment necessary to repair and maintain, as specified, the locomotive and to ascertain correct operation of all specified functions.

9.2 Test Points

9.2.1 Ride

The locomotive shall include a nominated accelerometer mounting point. This mounting point must be directly on the sprung body structure of the locomotive and must not be dynamically isolated any further.

The mounting point must provide a horizontal surface (with respect to the track) of ferrous (magnetic) construction on which clearance must be provided for a 25mm x 25mm x 100mm (in longitudinal direction) device, with clearances.

The mounting point must be within the main body structure but readily accessible and such that the fitting and removal of an accelerometer does not require the removal of any locomotive component or fixed / bolted bodywork.

The mounting point must be such there is a route for a cable to the exterior of the locomotive at high level

Should the locomotive comprise a number of entities separated by some form of coupling device(s), then each entity shall include a nominated accelerometer mounting point as described above. The judges will decide which such point is used for the challenge

10 Performance Demonstration

10.1 General

The Team shall demonstrate the performance of the locomotive relative to others produced against the same specification via a number of tests

Full details of the competition are set out in the Railway Challenge Rules

Performance demonstration will incorporate the haulage of a trailing load of up to 1800kg (note that the ratio of un-braked trailing load mass to locomotive mass will be taken into account during brake rate assessment)

Appendix 1 - Table of Revisions

General

The following table describes any significant changes made relative to Version 1 of the Railway Challenge 2026 Technical Specification

Typos and format changes will not be listed

Revisions

Table 1 - Table of Revisions

Clause	Change Date	Change
6.2.2	23.10.2025	Clarification re. auto-coupler height adjustment