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The Railway Challenge

The Railway Challenge

- Why a Railway Challenge?
- What is it?
- Where is it held
- The challenge weekend
- The entries
- Lessons
- The results

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Why a Railway Challenge?

- 87,000 UK engineers required, only 51,000 recruited
- Now 1.5 billion annual rail passenger journeys, twice that of 1994. Same as 1914 figure with half network size
- NSARE forecasts 3,100 new technicians/ engineers required over the next five years
- Only one university with railway engineering degree - 47 automotive and 43 aeronautical degree courses
- IMechE Formula Student first run in 1998, now 100+ entries
- Image of rail engineering

VS

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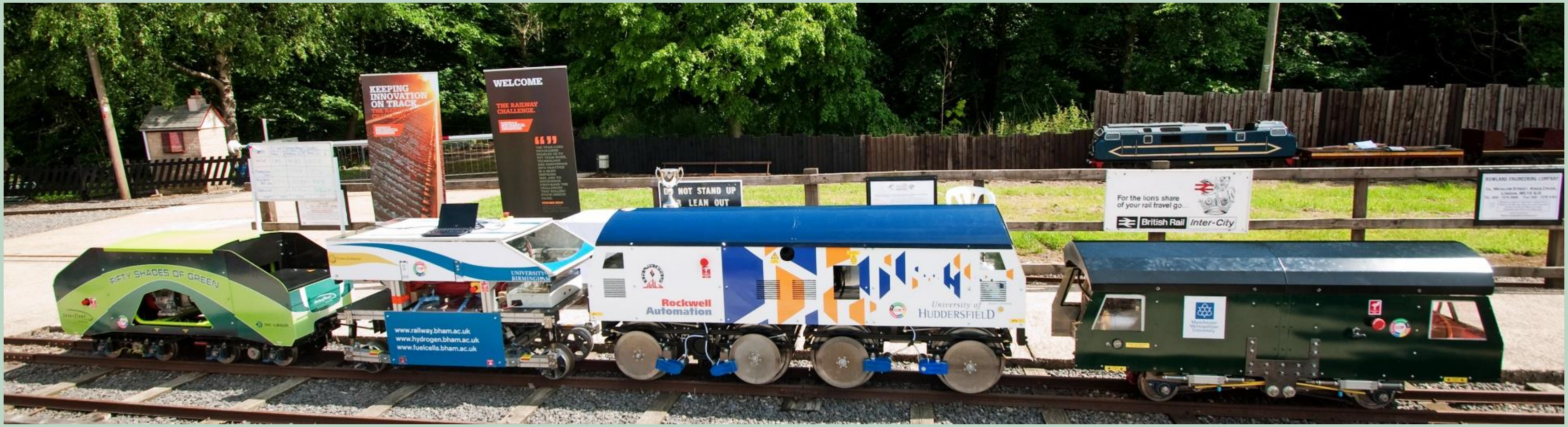
What is the Railway Challenge?

- Teams of students and apprentices to conceive, design and manufacture a ‘10$^{1/4}$ inch’ gauge locomotive to a performance specification
- Few restrictions on overall locomotive design
- Teams compete against other teams in a series of track based and presentation challenges
- First run in 2012



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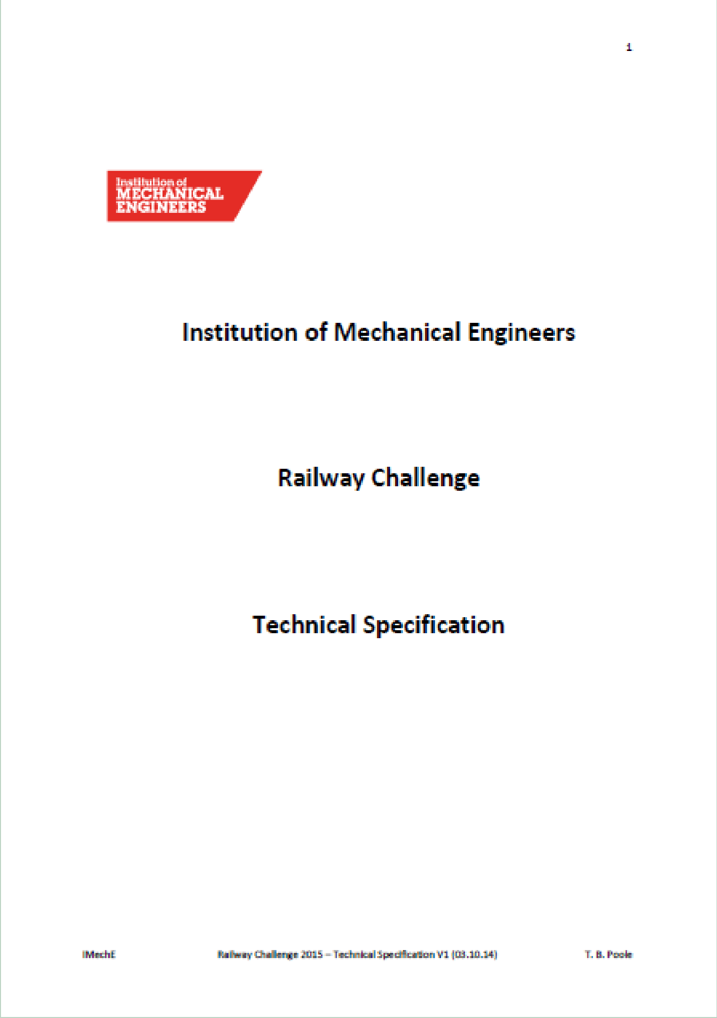
Technical Specification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Technical Specification

IMechE Railway Challenge 2015 – Technical Specification V1 (03.10.14) T. B. Poole

Technical Documentation:

- Design report & calculations
- As built drawings
- Manuals and data sheets
- Safety Analysis
- Bill of materials
- Structural and running gear calculations

Operational environment

- Remote operation from trailing load
- Dynamic loading gauge
- Track parameters
- Weather

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Technical Specification

Specific Requirements

- Maintainability and Reliability
- Operate for 3 hours without refuelling (5 km/h on 5% gradient with 400 kg trailing load), refuel in less than 90 seconds
- 95% recyclable materials
- Maximum weight 2,000 kg, max axle load 500 kg
- Max Speed 15 km/h
- Energy storage to deliver tractive effort
- Braking systems and performance
- Indications including energy meter
- Fire Protection
- Body markings
- Tools test equipment and test points

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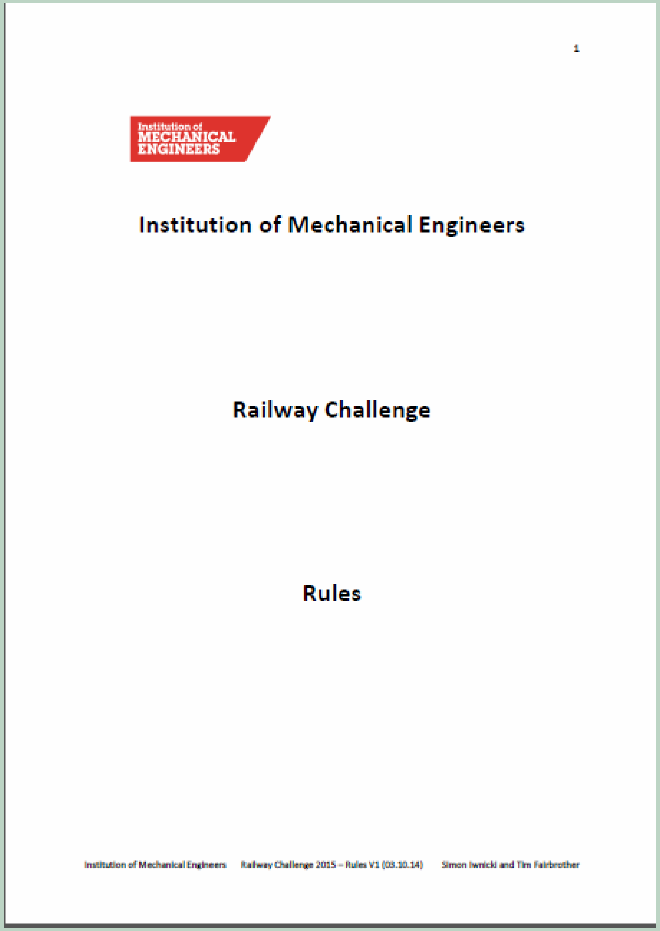
Rules



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Rules

General Rules, include eligibility

- Engineering Student or up to 2 years since graduated
- Registered on MPDS for upto 2 years
- An apprentice

Track Challenge Specifications

- Energy efficiency (300)
- Energy storage (300)
- Traction (150)
- Ride comfort (150)
- Noise (150)
- Maintainability (150)

Presentation Challenges

- Design (150)
- Business case (150)

Reliability

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Track Challenge Specifications

Energy Efficiency - Amount of energy to operate locomotive between two points

Energy Storage – Locomotive is stopped using energy recovery system that has no energy stored in it beforehand. The distance it can then travel using stored energy only is measured

Traction Challenge – The time taken to travel between two points from a standing start

Ride Comfort – Assessed by accelerometer mounted directly on body structure

Noise – Starting and by-pass noise measured during Traction Challenge

Maintainability – Assessment of ease of removal of major components

Reliability – 150 points added if no failure during event. 10 points deducted for each failure, 20 if external assistance is required

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Held at Stapleford Miniature Railway

- Not usually open to the public
- Central location near Melton Mowbray
- 2 miles of track, including a 1 in 80 gradient
- Great support from Friends of Stapleford Miniature Railway

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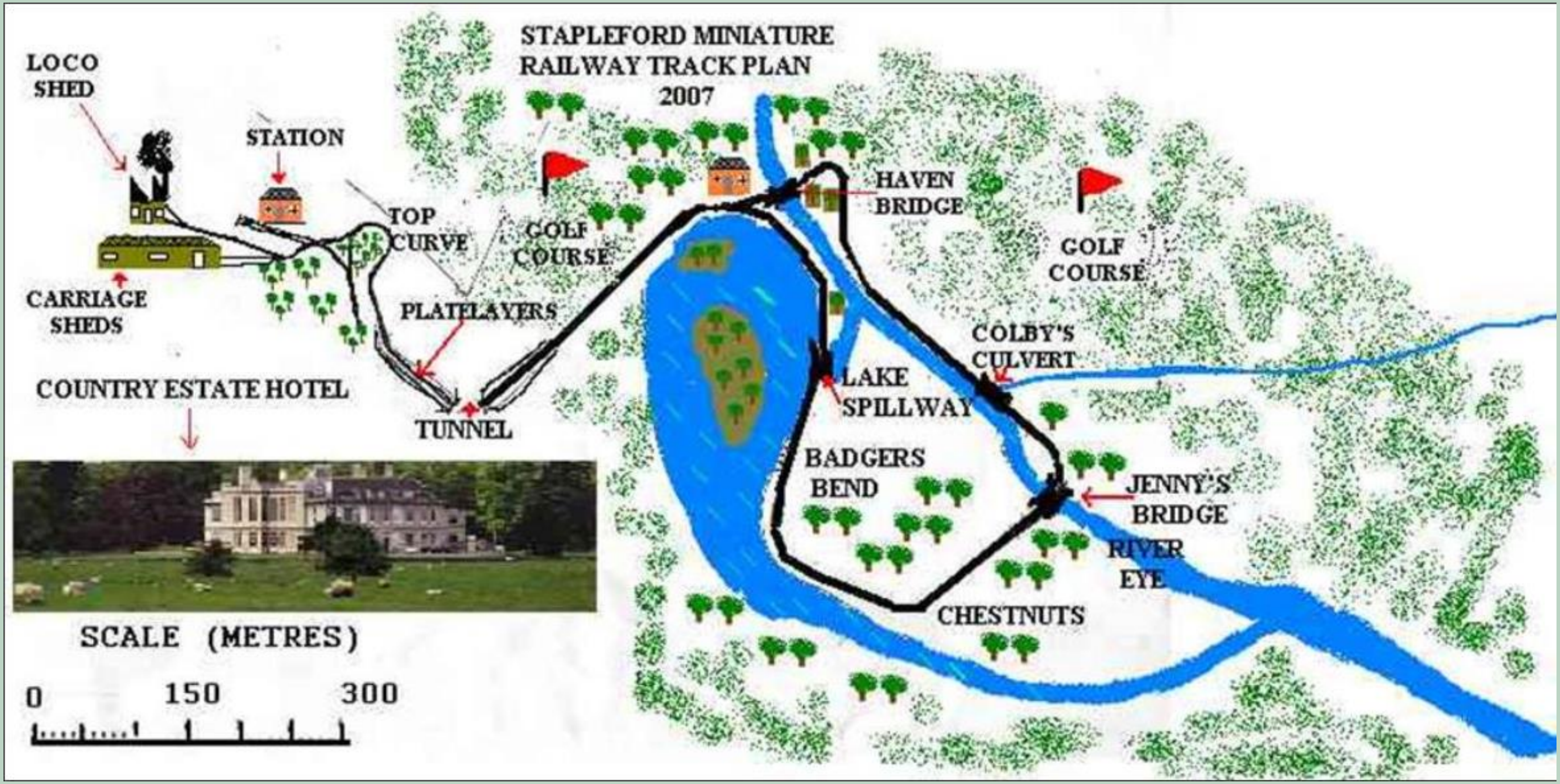
The Stapleford Miniature Railway



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2014's entries

University of Birmingham

Interfleet

University of Huddersfield

London Underground

University of Sheffield
Ran out of time - was to use petrol generator with AC/DC converter powering DC motors and energy recovery using spring and flywheel

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University of Birmingham

- Development of previous entries 2012 and 2013
- Modular aluminium frame
- Powered by 1.1 kw Hydrogen Fuel Cell to continuously top up 4.4 kWh traction power batteries via supercapacitors.
- 48V traction supply controlled by Roboteq controller using bespoke software, tachometer and current detection
- Two axles with direct gear drive from nose suspended traction motors. Larger wheels than previous entry
- Main brake is motor dynamic braking. Pneumatic disc brake for slow speeds, emergencies and parking brake
- Chevron spring primary suspension, rubber buffer secondary suspension
- Robust simple analogue control system replaces previous wireless system

2012 & 2013 entry

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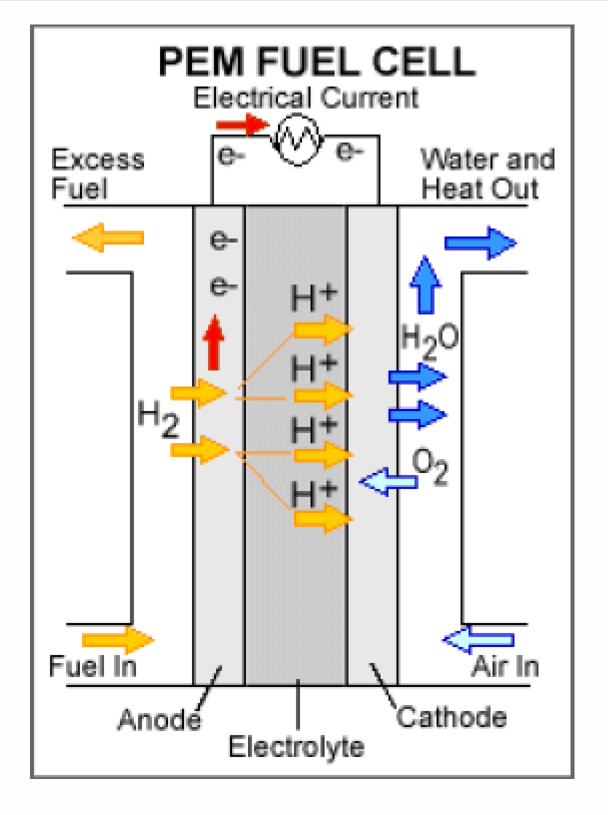
ReliOn E-1100™ Hydrogen Fuel Cell

In a Proton Exchange Membrane (PEM) fuel cell hydrogen (H2) is split into two protons (H+) that diffuse across the electrolyte membrane, whilst the two liberated electrons travel around an electrical circuit.

The protons, electrons and hydrogen combine with oxygen (typically from the air) to release water.

This process only forms water, electricity and heat



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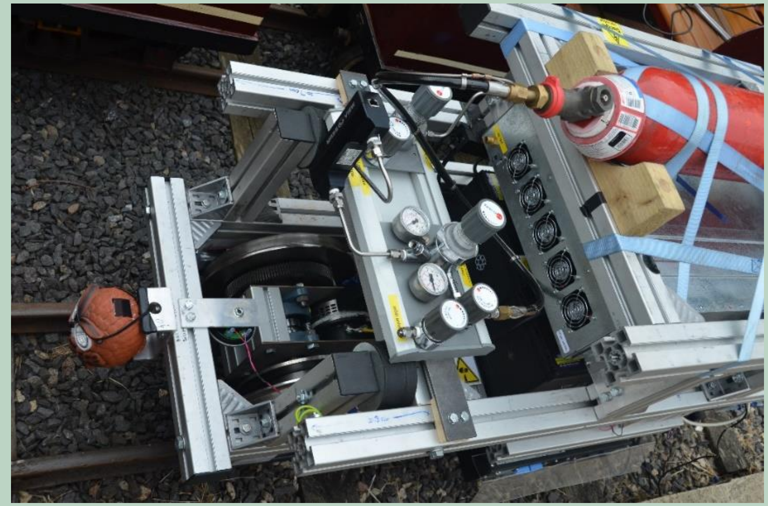
2013

2014



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Interfleet

- Development of previous loco entered in 2012 and 2013
- Powered by 3.9 kW 230V AC petrol generator
- Brushless DC motors provide traction and braking controlled by two 4 quadrant controllers
- Re-generative braking stored in supercapacitors during braking
- Two bogies each with one motor driving both axles via a driveshaft and sprocket & chain drive
- Primary suspension 2 axlebox coil springs, secondary suspension 2 dampers and height raisers supporting 4 springs
- Parking and emergency brake is a failsafe electric clutch brake

2013 entry

First Locomotive built at Derby Locomotive Works for 45 years

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Interfleet – Driver’s Control

2013

2014

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University of Huddersfield

- Development of previous loco entered in 2012 and 2013
- Suspension incorporates rubber bushes, coil springs and antiroll bars
- Only one bogie is powered with chain driven axles from single motor
- Energy recovery system on uses clock springs connected between two axle mounted cages. One cage could be locked to axle by an electromagnetic clutches, whilst other could locked to the frame by a brake band. 8 turns of the axle load spring to its maximum storage
- 7kW petrol generator set 3-phase 230 / 400 dual voltage. Traction motor drive is by a Powerflex 755 AC drive controlled from a Programmable Logic Controller. Remote locomotive control is by an Android tablet.
- Braking is by failsafe spring-loaded pneumatically operated callipers operating on discs attached to each axle.

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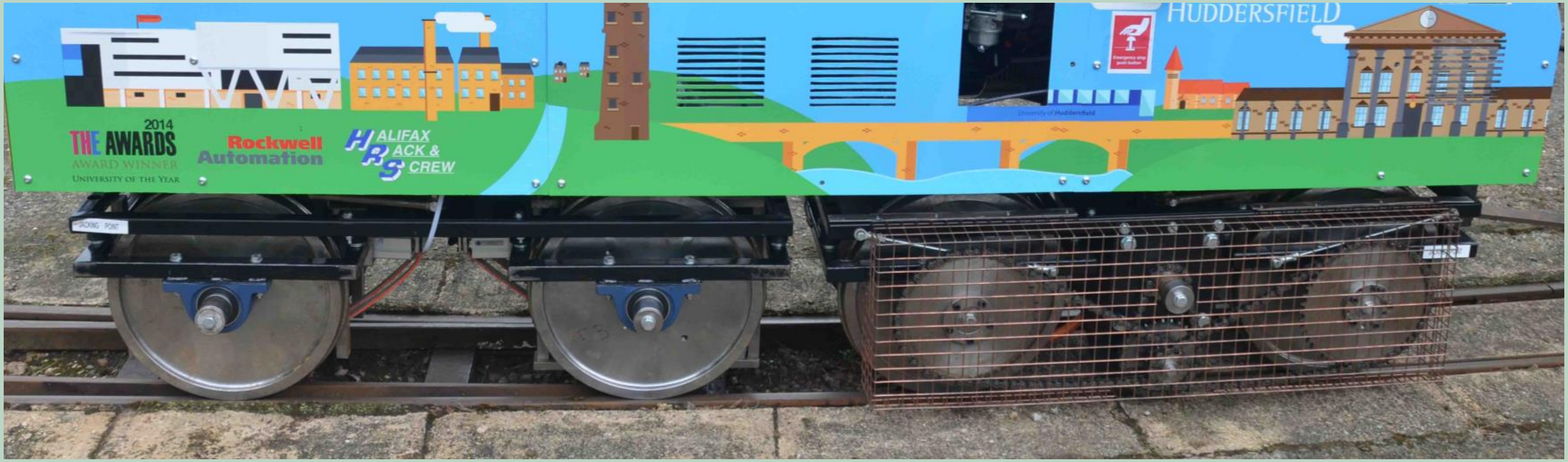

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London Underground

- New entry
- 5.5 kVA petrol generator powers two 1.1 kW 3 phase AC induction motors via motor invertors. Motor drives axles by chain and sprocket.
- Primary suspension axle bearing springs, secondary suspension two airbags per bogie
- Umbilical cable between Control Box and train. Two microcontrollers monitor systems using RS422 standard and control locomotive by bespoke C++ code
- Energy storage by hydraulic diaphragm balloon accumulator, pressurised to 30 bar by a hydraulic motor during regenerative braking. A hydraulic motor on other bogie powers locomotive when pressure released
- Also dynamic braking through resistors and parking / emergency braking by power-to-release electro-pneumatic disc brakes

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Earlier entries

Derby Independent Team – 2012

- Aimed to demonstrate a low cost entry – circa £2,000
- No energy storage
- Did not compete as power diodes burnt out

Manchester Metropolitan University – 2012 & 2013

- First entry to feature mechanical energy storage. Used at low speed in addition to super capacitors
- Adjustable radial arm suspension

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Earlier entries

Manchester Metropolitan University

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The Challenge Weekend

Day 1 – Testing, Scrutineering and Presentations

Testing - For some teams this was the first time their locomotive had been tested on track

Scrutineering - To participate in challenges teams must collect a full set of scrutineering stickers from judges on basis of confirming design calculations, inspections and physical tests

Presentations - 10 minute presentation; 10 minutes for questions
Teams considered to be representatives of a design consultancy producing a prototype locomotive which they wish to sell to a 'large corporation'
Questions also asked about team's design report

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Testing times

Problems experienced included:

- drive chains off sprockets
- loose electrical and pneumatic connections
- electronics overheated by the adjacent generator set
- engines overheating
- low drive chain causing a derailment
- outside kinematic envelope

As well as those associated with a "real" railway environment e.g.

> "Kamil Hashmi is struggling to find his locomotive's control system fault. In the laboratory he could listen to relays clicking but in a noisy environment he can't diagnose faults this way"

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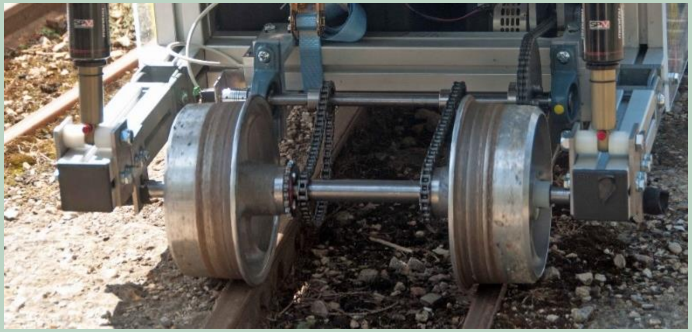
Testing times



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The Challenge Weekend

Day 2 – The challenges

- A judge for each challenge including one on the train
- FSMR provide a rescue train and a steam train for spectators

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Energy Storage Challenge

"no energy other than that gained from braking the locomotive and the coupled load must be stored"

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Noise Challenge

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Some Lessons

For IMechE after first challenge

Mass and rolling resistance do not scale equally, so Stapleford's 1 in 80 gradient is not as formidable as full sized railway. Hence applying regenerative braking stopped the miniature train instead of just retarding it

Team's views on most difficult part of the challenge:

- Energy storage
- Managing suppliers
- Deciding when to fix design
- Control system and filtering out petrol generator spikes

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Some Lessons

Successful teams need to:

- Test their locomotive before the challenge on one of the UK's many 10 ¼ inch gauge railways to ensure it works "out of the box"
- Understand the limitations of standard components. A failed chain could undermine all the hard work done to develop an innovative feature.
- Effectively project manage their time. A component that is 99% complete is useless.
- Make a good business case presentation that includes engineering, reliability, cost and other benefits that would make the customer want to buy the locomotive.

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2014 Results

Birmingham	Once again showed the way in green technology and won the noise challenge
Huddersfield	Won the business case Challenge.
London Underground	Won energy recovery and ride comfort
Interfleet	Won traction challenge with the most reliable locomotive

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Overall winner – London Underground

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Quotes

"The different and innovative designs from the same specification were impressive"

"In designing and building their own locomotives, the young engineers faced many real world operational, design and project management problems which provided a great learning experience"

"The Railway Challenge is a great way to promote innovation and provide young rail engineers with the opportunity to show what they can do as well as giving them the necessary skills to promote innovation"

"It encourages innovative thinking and may result in a Railway Challenge innovation appearing on the real railway"

For these reasons, UK railways will benefit greatly from the IMechE's Railway Challenge.