Very Light Rail Development

Andreas Hoffrichter, PhD
Research Fellow
Technical Lead for the Drive System on the Very Light Rail Vehicle

10th International Hydrail Conference
Mooresville, NC, 22 June 2015
Content

• Background to The University of Warwick and WMG
• Background to Very Light Rail
• Very Light Railcar Concept
• Concept Hybrid Drive System
• Very Light Rail Innovation Centre
• Summary
The University of Warwick, located in Coventry, United Kingdom (UK)

- 50th anniversary this year, received Royal Charter of Incorporation in 1965
- Been a top 10 UK university the entire period
- One of the top 100 university in world, currently placed 61st in QS annual world university ranking

Warwick Manufacturing Group (WMG)

- Established in 1980 to facilitate knowledge creation and technology transfer for industry
- An academic department of The University of Warwick
- More than 500 staff working across 6 buildings on the main campus

WMG focuses on:

- applied research in collaboration with industrial partners who provide “market-pull” and established routes to market
- Innovative teaching programmes (undergraduate, diploma, masters and doctoral) to meet the needs of companies
- More than 400 technical staff from Tata Steel Automotive, Jaguar Land Rover & Tata Motors European Technical Centre are accommodated within our facilities
WMG centre HVM Catapult

Focussed on Low Carbon Mobility

Lightweight Technologies Centre of Excellence

Propulsion & Energy Storage
Battery Characterisation and Electric / Hybrid Drives Development

Novel Battery Chemistries
Development & Scale-Up via Pilot Line

Materials & Manufacturing

Measurement & Characterisation

Digital Validation and CAE

Systems Engineering & Integration

Real World Optimisation & User Orientated Products

Target Market Sectors
WMG Research Interest in Rail

- Mainline passenger rail vehicles and associated infrastructure can be categorised as HEAVY and EXPENSIVE and light rail vehicle solutions are often not much better.

- The rail industry is still a conservative community – averse to adopting technology from other sectors.

- Reducing vehicle weight cuts energy consumption and allows the use of lightweight track structures, cutting the installation and maintenance costs substantially – there is an opportunity to develop a new generation of very lightweight rail vehicles for new urban shuttle services and regenerated rural feeder routes and with it establish a new industry segment in the UK manufacturing such vehicles and associated equipment.

- **VISION** – to build a portfolio of projects applying lightweight structures technology and high efficiency propulsion solutions to the emerging very light rail sector and in due course engage in light/heavy rail as opportunities emerge.

- WMG recently selected by Future Railway as one of 3 universities to form a Centre of Excellence in Rolling Stock Research.
The Future is Very Light Rail
# Very Light Rail

<table>
<thead>
<tr>
<th>Mainline Railway</th>
<th>Light Rail / Tram-Train</th>
<th>Regional Railway / Railbus</th>
<th>Very Light Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Relatively heavy vehicles</td>
<td>• Infrastructure designed for lighter vehicles compared to mainline railway</td>
<td>• Operation on mainline, heavy railway infrastructure</td>
<td>• Operation primarily on light rail infrastructure</td>
</tr>
<tr>
<td>• Infrastructure designed to carry heavy trains</td>
<td>• Operation on shared right-of-way (tram) or on segregated (light rail) alignment</td>
<td>• Usually self-powered</td>
<td>• Self-powered</td>
</tr>
<tr>
<td>• Maximum axle load in the UK 25t</td>
<td>• If the vehicles operated on mainline and light rail then they are referred to as tram-train</td>
<td>• Mass of a typical single railbus vehicle is ~40t</td>
<td>• Mass of a single very light rail car is anticipated to be &lt;18t</td>
</tr>
<tr>
<td>• Power supply through wayside electrification or self-powered trains</td>
<td>• Usually the power supply is through wayside electrification</td>
<td>• Typical axle load ~10t</td>
<td>• Target axle load &lt;5t</td>
</tr>
<tr>
<td>• Mass of a typical single, powered carriage is ~45-50t</td>
<td>• Mass of typical light rail train is ~ 40t</td>
<td>• Typical vehicle mass per linear meter ~1.6t</td>
<td>• Anticipated vehicle mass per linear meter &lt;1t</td>
</tr>
<tr>
<td>• Typical axle load for a Diesel Multiple Unit train ~12t</td>
<td>• Typical axle load ~6t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Typical vehicle mass per linear meter ~2t</td>
<td>• Typical vehicle mass per linear meter ~1.2t</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Radical Train: Very Light Railcar

• Network Rail and the Rail Safety and Standards Board (RSSB) are encouraging new thinking in the area of very lightweight rail vehicles including future interoperability with “mainline traffic”

In 2014 the Revolution VLR Consortium was awarded £1.6m by Future Railway towards a £4.2m project to develop a radical train demonstrator

– The consortium, led by Transport Design International (TDI), includes WMG, Trelleborg PPL, Unipart Rail and Prose, with Cummins as the selected engine supplier

– The vehicle will feature 2 lightweight self-propelled bogies, each incorporating diesel-electric hybrid propulsion plus lithium titanate energy storage for regenerative braking and zero-emission launches from stations. The vehicle will use a modular lightweight segment body structure to minimise construction costs

• Overall objectives are:

  – Unladen vehicle mass less than 18 tonnes for a 18m car
  – Target selling price of £500k

• Solution is based on well proven technologies already in use in other transport sectors
Current Status

• Project commenced June 1\textsuperscript{st} 2014; 2 year time scale to completed demonstrator

• In Year 1:
  – Conceptual Bogie Design & Railcar Configuration – April 2015 ✔
  – A full powertrain to be assembled and tested on WMG’s dynamometers – Autumn 2015
  – Completed CAD drawings for bogies and body with 3D printed models and 3D visualisations – Autumn 2015

• In Year 2:
  – Manufacture of 2 self-powered bogies plus lightweight body, assembly of vehicle and initial vehicle tests
VLR Railcar Gauge Drawing

- GE/RT8573 C1 GAUGE (STATIC UPPER GAUGE)
- RSSB PG1 SUBURBAN GAUGE

Dimensions:
- Overall Vehicle Width: 2800mm
- Overall Vehicle Height: 3800mm
- Maximum Height: 3600mm
- Platform Height (ARL): 915mm
- Track Gauge: 1435mm
- Offset: 2540mm
- Maximum Width: 2820mm
Vehicle Exterior
Body Side Panel Assembly
Concept Vehicle Interior
VLR Railcar Drive-System

- Two independent self-powered bogies, providing redundancy
- Diesel-Electric, but other prime movers possible in the future, for example, Natural Gas Engine or Hydrogen Fuel Cell
- Series-Hybrid drive-system
  - Diesel engine and lithium-titanate batteries integrated into bogie
  - Direct drive, traction motors with magnetic gearing rather than mechanic
- Diesel engine does not operate in stations and when accelerating away from the station
- Regenerative braking possible and intended as the service brake
- Approximately 200kW per vehicle, 100kW per bogie
- Maximum acceleration around 1m/s²
- Powered bogies are an individual module that can be sold in its own
- Several challenges:
  - Mass target of railcar, bogies have to contribute to overall reduction
  - Volume of components and integration into the bogie
  - Shock acceleration and high forces in the railway environment, reliable operation of equipment required
Tractive Effort Graph

- Force in kN vs. Speed in km/h
- Graph showing three curves:
  - Blue: Resistance to Motion
  - Red: Tractive Effort
  - Green: Acceleration Force
Drive System Concept
Self-Powered Bogie Concept Plan
Proposed Innovation Hub

• Centre where next generation very light weight rail vehicles for domestic and export markets can be create

• What is needed is an innovation hub to support industry
  – providing a neutral space for pre-competitive research
  – coordinating strategic initiatives & managing collaborative projects
  – lobbying regulatory bodies, funding sources and Government
  – hosting conferences and exhibitions
  – supporting the education of the next generation railway engineers and managers
  – training workers for roles in the expanding very light rail sector
  – facilities for construction of prototype vehicles
  – Small and Medium Sized Enterprise (SME) incubator units
  – Open-Access test facilities including a test track for vehicle, systems and infrastructure trials
  – Public exhibition of future rail developments
Current Status

- £50k of funding provided by Dudley Metropolitan Borough Council (DMBC) supported:
  - Initial site survey and first pass architectural drawings
  - Cost estimates for Innovation Centre and Test Track are £20m + £15m
  - First pass economic benefit assessment
- £4.5m Local Enterprise Partnership (LEP) funding allocated in January 2015
- £50k of further funding allocated by DMBC to support refinement of plans
- Project team preparing application for £15m European Regional Development Fund (ERDF) bid to be submitted in spring/summer 2015
Dudley: Castle Hill Site

- Previously occupied by Dudley Station followed by a Freightliner Terminal
- Abandoned rail line adjacent (running from Stourbridge to Walsall)
Proposed Test Track Route
Innovation Centre for Very Light Rail
Front Elevation
Innovation Centre for Very Light Rail
Rear Elevation
National Innovation Centre for Very Light Rail
Main Workshop
Beyond the Innovation Centre: a Shuttle Service from Dudley Port to Local Visitor Attractions
Then the Black Country VLR Network!
Summary

• Very Light Rail systems developed to provide lower-cost alternative for urban and regional railways
• Vehicles are self-powered
• VLR demonstrator vehicle under development
  – About half the mass of a traditional railbus
  – Diesel-Hybrid drive system, with fully electric operation for short periods, such as at stops and accelerating from stations
  – Drive system integrated into the bogie
• Very Light Rail Innovation Centre
  – Building on WMG expertise of bringing academia and industry together
  – Develop new VLR vehicles
  – Laboratory and test track facilities