Stuart Hillmansen
RRUKA Academic Co-Chair
RRUKA: a brief overview

• Builds on foundations of EPSRC-funded virtual research centre

• Founded in 2010 and co funded by:

• A partnership between Britain’s rail industry and UK universities with the following aims:

- SUPPORT AND FACILITATE RAILWAY RESEARCH
- IDENTIFY RESEARCH AND APPLICATION OPPORTUNITIES
- IMPROVE UNDERSTANDING OF RESEARCH NEEDS
- PROVIDE SOLUTIONS TO THE RAILWAY INDUSTRY
Access to a wide range of expertise

RRUKA has **49 Institutional Members** and over **350 individual members**

**ENGINEERING** (mechanical, civil, electrical, chemical etc.)

**HUMAN FACTORS, PSYCHOLOGY**

**COMPUTER SCIENCE**

**ECONOMICS, MATHS & STATISTICS**

**SOCIAL SCIENCE**

**OTHERS:** Material science, mechatronics, chemistry, robotics etc.
How do we achieve our aims?

Workshops & events
*Problem solving, networking, dissemination*

Improving industry & academia communication

Maintaining map of Universities capabilities and expertise
*RRUKA capability statement*

Facilitate networking and collaboration

Support industry vision
*Academic Response to the RTS*

Providing access to research and funding opportunities
RAS for Rolling Stock Maintenance: Introduction

The strategy

The challenge

Knowledge transfer & sharing

Opportunities
The Strategy...

2.92 Cost effective upgrades and fewer maintenance processes.

3.59 New technologies in the industry will alter the workplace and automation could take over repetitive and arduous tasks.

4.24 Automation of a wider range of maintenance operations lowers the risk to maintenance personnel.
RAS for Rolling Stock Maintenance: Introduction

The strategy

The challenge

Knowledge transfer & sharing

Opportunities
David Lane  FREng FRSE
Professor of Autonomous Systems Engineering
Heriot-Watt University, Edinburgh, Scotland, UK
Edinburgh Centre for Robotics
A £35M Joint Venture between Heriot-Watt & Edinburgh Universities

Field Systems: Interaction Spaces : MOBOTARIUM : Enablers

edinburgh-robotics.org    d.m.lane@hw.ac.uk
Innovation Ready
Spin outs and licensing

edinburgh-robotics.org  d.m.lane@hw.ac.uk

Distinctly Ambitious
www.hw.ac.uk
RAS 2020
Robotics and Autonomous Systems

A national strategy to capture value in a cross-sector UK RAS innovation pipeline through co-ordinated development of assets, challenges, clusters and skills / July 2014
3.0 Markets and Opportunities

Commercial and Government Market Impacts
4.0 Strategic Actions

5 Interconnected Themes
4.0 Strategic Actions

Tangible and Intangible Assets
4.0 Strategic Actions
4.0 Strategic Actions
4.0 Strategic Actions
Robots Use the Cloud
The Arms, Legs and Sensors of Big Data
RoboEarth and Knowrob
Knowledge Processing for Robots

- OWL: Web Ontology Language
- Cyc ontologies from semantic web
- Prolog for reasoning
- WikiHow for instructions
- Statistical Relation Learning
- ROS Middleware

edinburgh-robotics.org   d.m.lane@hw.ac.uk
InteGRail consortium

EU FP6 2004-9

edinburgh-robotics.org  d.m.lane@hw.ac.uk
Ontology
Semantic Relational Modeling
Ontology
Semantic Relational Modeling

Common Ground For Different Types of Diagnostic System

Store’s The Target System Design Information
Skill Learning

Turning a valve from a hovering AUV
Skill Learning

Failure Recovery
Take-Aways
Messages to take home

Assets & Challenges breed Innovation

Robots are the arms, legs & sensors of Big Data

INTEGRAIL, ontology, prognostics [www.shift2rail.eu]

Machine Learning can make dumb-iron smart
David Lane  FREng FRSE
Professor of Autonomous Systems Engineering
Heriot-Watt University, Edinburgh, Scotland, UK
RAS for Rolling Stock Maintenance: Introduction

- The strategy
- The challenge
- Knowledge transfer & sharing
- Opportunities
How is rolling stock maintenance carried out?

David Polhill

RRUKA Robotics Workshop
20 October 2015
What is maintenance?

What is a train?

What is needed for maintenance?

What is checked?

How it’s planned?
What is maintenance?

- **Maintenance** is the overhaul, repair, inspection or modification of an item
- Also included is cleaning inside and out
- Topping up – fuel, toilet water tanks
- Emptying toilet effluent tanks
What is a train?

- A train is a form of rail transport consisting of a series of vehicles that runs along a railway track to transport cargo or passengers.
- Motive power is provided by a separate locomotive or individual motors in self-propelled multiple units.
- Simple?
Train size
Where & how to maintain?

Diagram of a depot designed principally for EMU trains. A DMU or locomotive depot would be similar but with the addition of a refueling area separate from the main buildings.

Association of Train Operating Companies
Depots

• Many depots
• Currently over 100 for passenger trains
Maintenance

Consists of checking consumables – brake pads, pantograph carbons
Replenishing fluids – screen wash, diesel
Measuring – wheels
Inspecting – undersides
Lots of looking, listening, smelling and touching.
Changing seat covers
Washing & vacuuming floors
Cleaning toilets, cabs, saloons
Washing the exterior
Emptying toilet tanks
The “Art of Maintenance”

Ideally maintenance needs to be undertaken the day before things break!
Automation

• NDT
Automation

- Wheel profile
Automation
How is maintenance planned?

- Things degrade at differing rates
- Depot capacity
- Resources
- Written as a Maintenance Plan

Example of a periodicity table (3.1.8)

<table>
<thead>
<tr>
<th>No.</th>
<th>Maintenance Activity</th>
<th>Maintenance step</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC01</td>
<td>Air Compressor Intercooler Safety Valve – Change</td>
<td>X X</td>
</tr>
<tr>
<td>AC02</td>
<td>Air Compressor Oil Level &amp; Drive Shaft Guard – Check</td>
<td>X X X X X</td>
</tr>
<tr>
<td>AC03</td>
<td>Air Compressor Air Filter Element – Renew</td>
<td>X X X</td>
</tr>
<tr>
<td>AC04</td>
<td>Air Compressor Filter &amp; Oil – Change</td>
<td>X X X</td>
</tr>
<tr>
<td>AC05</td>
<td>Air Compressor &amp; Drive Shaft Coupling – Renew</td>
<td>X</td>
</tr>
<tr>
<td>AC06</td>
<td>Air Compressor Leakage – Check</td>
<td>X X X X X</td>
</tr>
</tbody>
</table>

Diagram showing maintenance schedule.
Train Maintenance – Understanding the Challenges

Mark Molyneux
Head of Engineering

20th October 2015
Train Maintenance Understanding the Challenges

- Industry Growth
- Expect The Unexpected!
- Human Factors 1/1
- Human Factors 1/2
Train Maintenance – Understanding The Challenges – Industry Growth

- GB Railways are booming!
- Prediction that number of vehicles will need to double in the next 30 years
- How will the railway accommodate these vehicles?
- Stabling?
- It’s a challenge to maintain and service the ones that we have already!
- Without a significant improvement in maintenance effectiveness we will have to double the amount of depot capacity.
Train Maintenance – Understanding The Challenges – Expect the Unexpected!

- Collisions / impact damage
- Things coming loose
- Things wearing out
- Things leaking
- Things seizing up
- Things corroding
- Component failure effects on duty cycles
- Weather / Interface Effects / Electrification
Train Maintenance – Understanding The Challenges – Human Factors - 1/2

• …and that’s before we get to the humans…..

• Human interventions
  – Maintenance errors
  – Modifications
  – Litter, dust and spillages….
  – Toilets
  – Vandalism

• Train Preparation challenge
• Despite it’s failings the Mk I human does have some good features:
  – inherent adaptability
  – widely available
  – can manage complex tasks
• “Artificial Intelligence is currently no match for natural stupidity…….”

……but that’s where you come in to prove me wrong!
MAINTENANCE: FUTURE CONCEPT
HITACHI RAIL EUROPE LTD
WHAT IS MAINTENANCE?

A METHOD OF ENGINEERING THAT ENSURES:

• Technology adheres to safety and performance obligations whilst in operation
• Work is only carried out when necessary
• Identifies how, why and when to carry out specific activities
MAINTENANCE IS NOT A PROCESS WHICH IS SET IN STONE
MAINTENANCE: FUTURE CONCEPT
HITACHI RAIL EUROPE LTD

PLANNING
Any good maintenance plan should be developed through application of analytical techniques with consideration to the following areas:

- Reliability
- Performance
- Obsolescence
- Logistic support
- Tooling
ANALYSIS - METHODS

Reliability – Application of Fault Tree Analysis through a RAMS plan

Performance – Modelling of the reliability assumptions against a fleet operation model

Obsolescence, Logistics and Tooling – Reliant upon data collection through a robust Life Cycle Cost methodology
ANALYSIS

The bottom line of analysis is to understand the Whole Life Cost associated with the product within the context of the project.

Costs will fluctuate dependant upon the contractual requirements even where a standard platform design is used.
THE EXAM PLAN

The schedule of works to be carried out on a frequency basis

These works can be generally split into 2 areas:

Preventative maintenance (PM)
Corrective maintenance (CM)
### THE EXAM SCHEDULE - PM

<table>
<thead>
<tr>
<th>Task Code</th>
<th>Task Description</th>
<th>Total Time (mins)</th>
<th>Frequency (days)</th>
<th>Daily</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A - Air System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHX001</td>
<td>Cab Equipment - Check Horn System</td>
<td>0</td>
<td>1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>ASX002</td>
<td>Sand Hopper Assembly - Sand Hopper top-up. Functional test via test button.</td>
<td>10</td>
<td>1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>B - Brakes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BBX001</td>
<td>Brake Pads - Inspect (Remote monitoring)</td>
<td>8</td>
<td>10</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>BZX001</td>
<td>Brake Control System - Check / Brake test</td>
<td>10</td>
<td>1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>BZX002</td>
<td>Brake Control System - Check / Functional test Brake Control System (CU Pressure Control; Watchdog; WSP)</td>
<td>20</td>
<td>50</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>C - Bodyshell</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Front Gangway - Clean</td>
<td>30</td>
<td>10</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Yes</td>
<td>Front Gangway - Visual Inspection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>D - Generator Unit (Diesel Engine)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E - Battery and Control Systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Battery - Visual inspection; Checking the charger voltage; Checking voltage of each cell; Check of contactor status; Manual and voltage test of load switch</td>
<td>60</td>
<td>50</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Yes</td>
<td>Save to split out battery task into 10 and 50 days (review IEP investigation results)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PLAN FOR THE UNPLANNED - CM

- CM cannot be scheduled only assumed
- Assumptions derived through reliability
- Impact cannot be underestimated, CM is failure based
- CM provides an opportunity through a risk based approach

The application of technology can resolve the challenge of corrective activities
PLANNING FOR MAINTENANCE STARTS BEFORE THE DESIGN STAGE AND MATURES THROUGHOUT THE DESIGN CYCLE
REMOTE MONITORING

Purpose - Use remote diagnostic monitoring in order to understand the status of all fleet equipment at all times

Benefits – Monitoring and recording mass data in this way allows predictive modelling of the probability of failure curve allowing not only failure prediction but also a shift to on condition maintenance
Example: Monitor train door condition by tracking the change in door motor currents over a given period.
Example: Monitor train door condition by tracking the change in door motor currents over a given period

If there are ~ 5600 doors on a fleet

~ £2000 in material per location

3 Overhauls during train life

Cost ~ £33.6 Mil in door motors alone

Not accounted for:
- Unit down time
- Man hours
- Impact on maintenance plan
REMOTE MONITORING

**“What”**
- RCM
- OEM
- CBM

**“How”**
- Depot Server
- SAP
- Work Order
- History
- Schedule Maintenance

**Maintenance Tasks**
- CBM
- Manual checks

**Technology Development**
- OEM
- New Development
- Develop
- Buy
- Cost/benefit

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AUTOMATED INSPECTION

Industry initiative to reduce number of manual inspections by adopting track based scanning equipment undertaking the following:

- Measurement of wheel profiles
- Measurement of brake pad, block and disk thickness
- Visual identification of components
- Inspection of pantograph carbon contact strips
- Automatic gauge profiling
- ...and even more
AUTOMATED INSPECTION

Uses visible and none visible wave frequencies for detection

- Processes raw data to determine equipment condition
- Automatically records key train component condition
- Reports on remaining life
- Automatically raises work order
AUTOMATED INSPECTION - LIMITATIONS

Fixed apparatus – Detection is dependant upon service pattern

Speed of surveillance – Limitations of electronics mean detection only possible at slow speed passes

Expensive – Modules need maintaining, Require validation to authorise use
AXLE MAINTENANCE

Axle performance and safety must be maintained to the highest standard as failures can be catastrophic

- Detection of axle faults when carried out manually is open to a high degree of interpretation
- Scanning the bore of a hollow axle is expensive, time consuming but offers a high detection probability
AXLE MAINTENANCE

Can existing technologies be adapted to allow axles to be automatically inspected whilst maintaining the highest standards of safety and providing exceptional detection probability?
INTEGRATED SYSTEMS

Reliance upon remote technology leads to challenges when considering the multiple system interfaces required to manage the technology and interpret the information.
INTEGRATED SYSTEMS

Supply chain management

DATA

CMMS

Scheduling

Data analysis

Reporting

Automatic scanner
INTEGRATED SYSTEMS

• Is there potential to apply AI and robotics to reduce human effort required to configure system interfaces and assist in the development of algorithms?

• Can technology developed through the IoT be applied to our industry to assist in the control and understanding of the data produced?
ADVANCED TOOLING

Ultrasonic axle tester

Wheel lathe
Wheelsets carry one of the highest costs for consumables on a rail vehicle, the industry has made continual efforts to optimize wheel life:

- Investment in expensive heavy tooling
- Highly dependant upon manual intervention
- Heavy workload
- Efforts have been target at prolonging wheel life by managing the wheel / rail interface and application of problem solving techniques
CHALLENGE – WHEEL SETS

Through the implementation of robotic technology reduce the time and costs associated with the maintenance of wheel sets while maintaining exceptional operational and safety performance
POTENTIAL FOR NEW TECHNOLOGIES TO ASSIST IN:

- ULTRASONIC AXLE TESTING
- WHEEL SET MAINTENANCE
- MAKING SENSE OF MASS DATA
- IMPROVING EXISTING TECHNIQUES
- REDUCING THE TIME UNITS SPEND IN A DEPOT
Panel session

**Moderator: Stuart Hillmansen**

David Lane
David Polhill
Mark Molyneux
James Pollard
Simon Jarret
Coffee Break

Next Session starts at 11:30am