S-CODE: Switch and Crossing Optimal Design and Evaluation

Professor Clive Roberts, University of Birmingham (c.roberts.20@bham.ac.uk)

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no 730849

Birmingham Centre for Railway Research and Education

- Railway research at Birmingham begun in the 1970s
- Nowadays we are a group of over 130 researchers and support staff with:
  - Network Rail's Strategic Partner for Data Integration and Management
  - UK Rail Supply Group's Centre of Excellence for Digital Rail Systems Innovation
  - IBM's global partner for railroad transportation
  - 2017 nomination for the Queen's Anniversary Award
  - Strong international collaborations in Singapore, China, USA, Japan, Malaysia, Thailand, Oman, Hong Kong and various EU
  - Aspirations to grow further to meet the demands of the UK and international railway industry

Birmingham Centre for Railway Research and Education (BCRRE)

Turnover of ~£5M/year

371 Academic papers over ths last 5 years

More than 80 international industrial collaborators

Over 350 current railway students

UNIVERSITY OF BIRMINGHAM | BCRRE

Railway Education at BCRRE

BEng/MEng in Railway Engineering
MSc in Railway Systems Engineering and Integration
MSc in Railway Risk and Safety Management
MSc in Railway Control and Communication Systems
MRes in Railway System Integration
PGCert in Urban Railway Transportation

Railway Research at BCRRE

1. Railway Control and Operations Simulation

2. Data Integration and Cybersecurity

3. Condition Monitoring and Sensing

4. Power and Energy

5. Aerodynamics

6. Climate Change and Weather Impact

7. Benchmarking, Systems Engineering and Safety

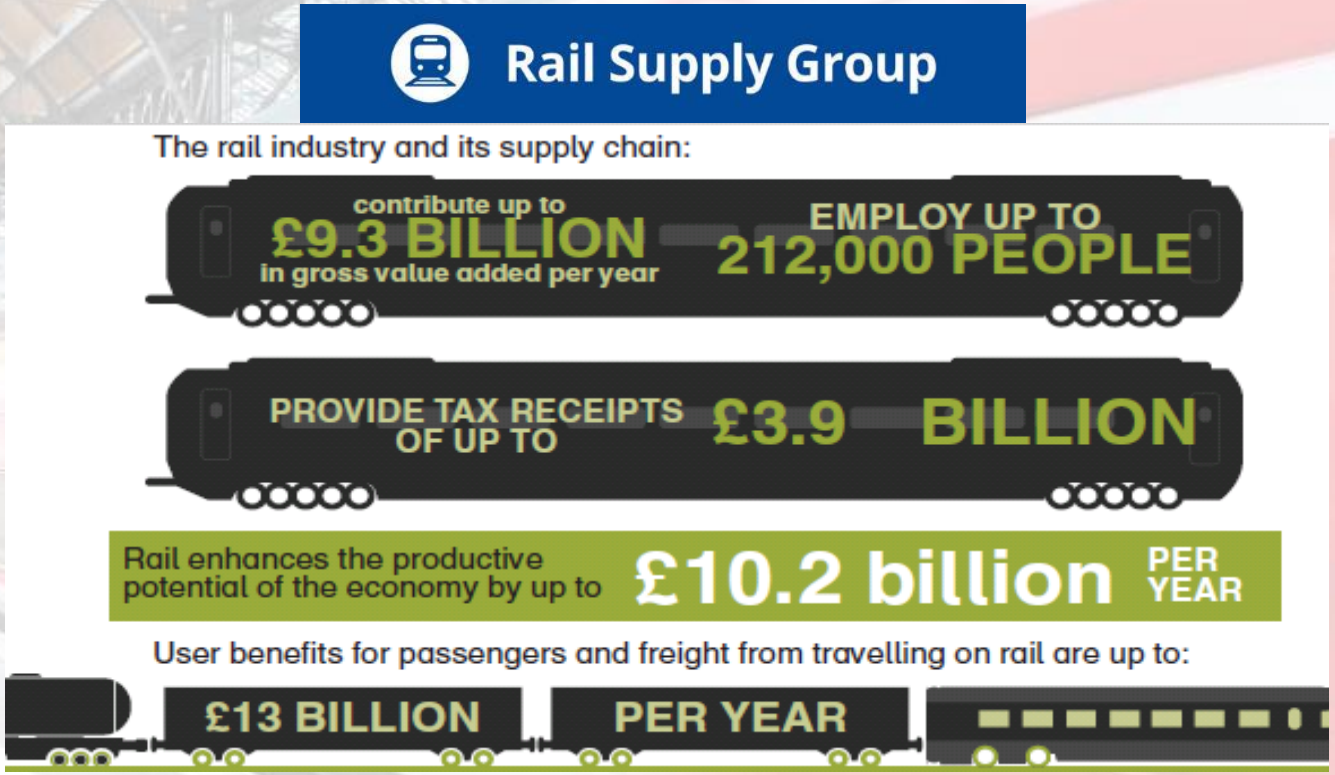
8. Computational Modelling

9. Geotechnical Engineering and Asset Management

New Technologies
and their application

- Additive Manufacturing
- Robotics
- Quantum Technologies
- …

UK Railway Research and Innovation Network (UKRRIN)



The RSG clearly recognise that investment in research and innovation capabilities will be essential to the delivery of these goals and aim to develop Centres of Excellence in key areas to support the industry

UKRRIN Partners

£64M of Private Investment (revenue and in-kind over 10 years)
£28M of Government Investment (capital over 3 years)
Support from Network Rail, HS2, TLG, RDG, RSG, RA, DfT, LEPs

ALSTOM SIEMENS BOMBARDIER SMRT

IBM northern RSSB UNIPART RAIL

BRITISH STEEL Railway Industry Association Progress Rail A Caterpillar Company THALES HITACHI Inspire the Next

AECOM ATKINS PANDROL TRACK SYSTEMS AGGREGATE INDUSTRIES

UKRRIN Centres of Excellence

Overall Lead: University of Birmingham

Digital (£16.4m capital): University of Birmingham

Rolling Stock (£10m capital): University of Huddersfield with University of Newcastle and Loughborough University

Infrastructure (£1.7m capital): University of Southampton with University of Sheffield, Loughborough University, Heriot Watt University and Nottingham University

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S-CODE: Switch and Crossing Optimal Design and Evaluation

- Funded through the first Shift2Rail Open Call (5 m€)
- Led by the University of Birmingham

- "The overall aim of the S-CODE project is to investigate, develop, validate and initially integrate radically new concepts for switches and crossings that have the potential to lead to increases in capacity, reliability and safety while reducing investment and operating costs".

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Key S-CODE Outcomes

1. The development and prototyping of a **modular whole system switch and crossing architecture that allows subsystems to be changed over the life of the S&C**. This will **enable innovations to be added as they become available**. The architecture and subsystems will be modelled to allow rapid development of further capabilities.
2. The design and prototyping of Next Generation Design components that can be incorporated into the architecture, using **new materials and technologies to create a variety of permanent way subsystems**.
3. The design and prototyping of a Next Generation Control subsystem that can be incorporated into the architecture, which will include an **'immune system' capable of self- adjustment, self-correction, self-repair and self-heal**.
4. The design and prototyping of Next Generation Kinematic subsystem that can be incorporated into the architecture, that includes **new actuation and locking philosophies that make use of concepts such as redundancy and 'limp-home'** through the use of novel actuators and mechatronic systems.
5. Analysis will be undertaken to **quantify the value of these innovations** from the perspective of: (i) reliability, (ii) life-cycle cost, and (iii) higher speed switches/train throughput.

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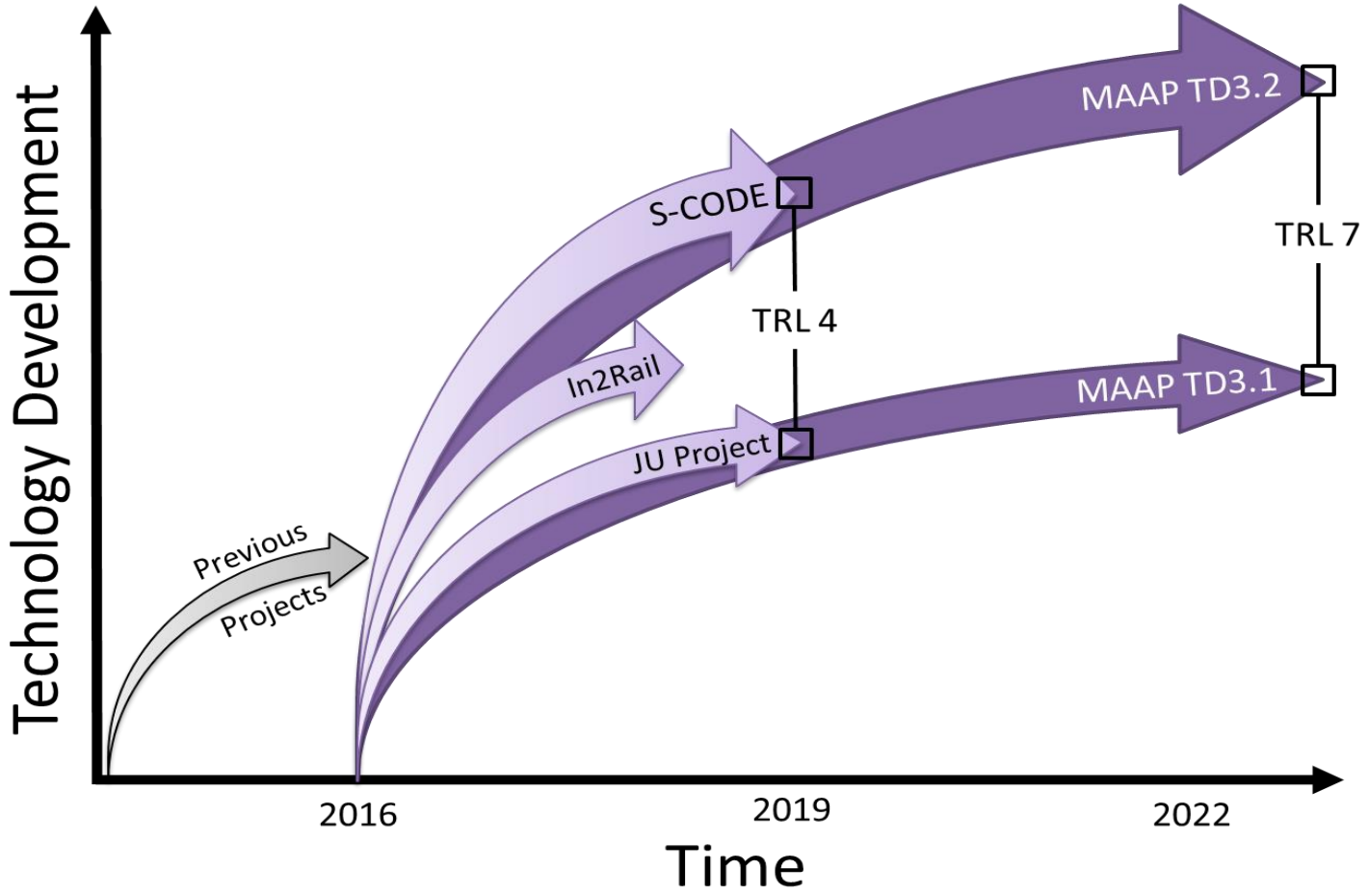
Links between S-CODE, In2Rail and In2Track (from S-CODE proposal)



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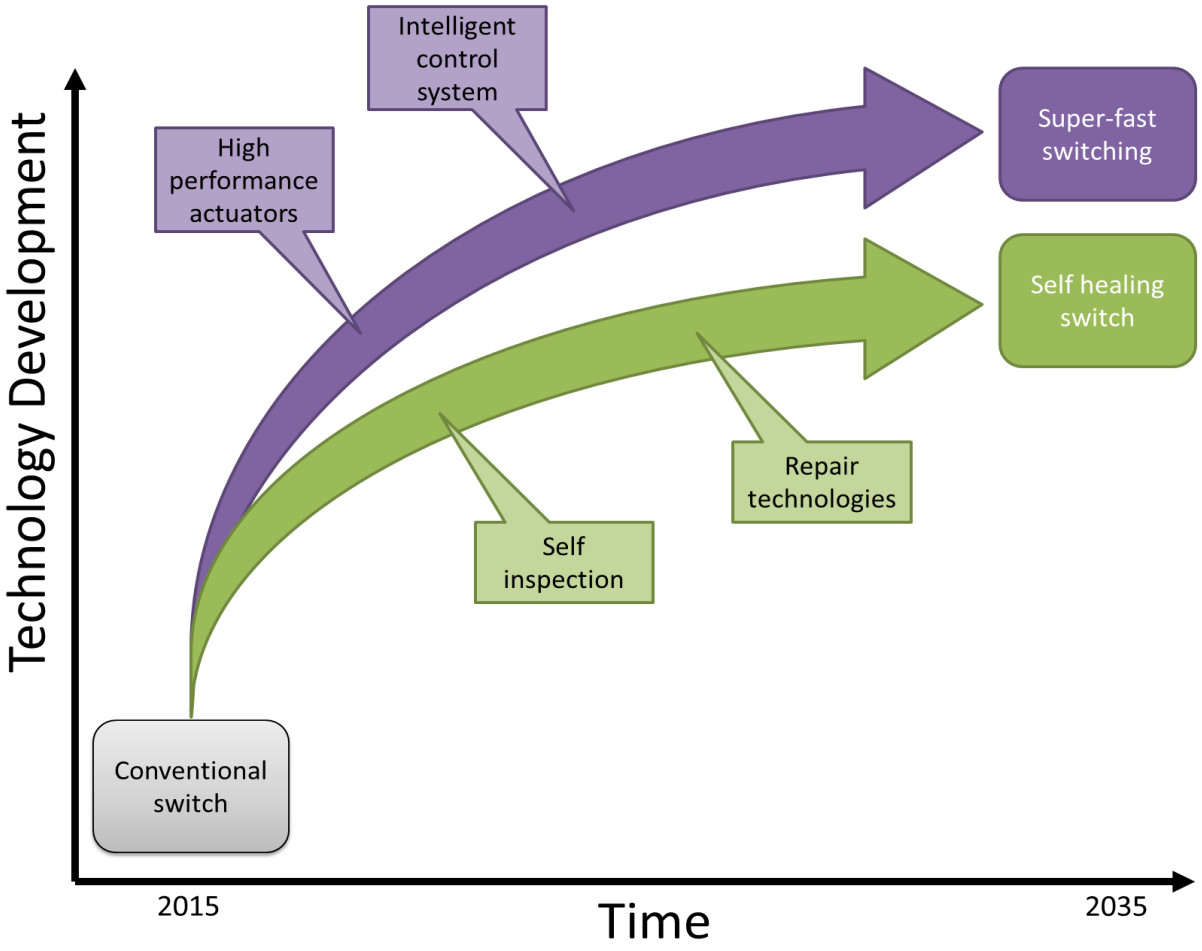
S-CODE technology development examples



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Phases of the project

Phase 1 – Start Nov ’16

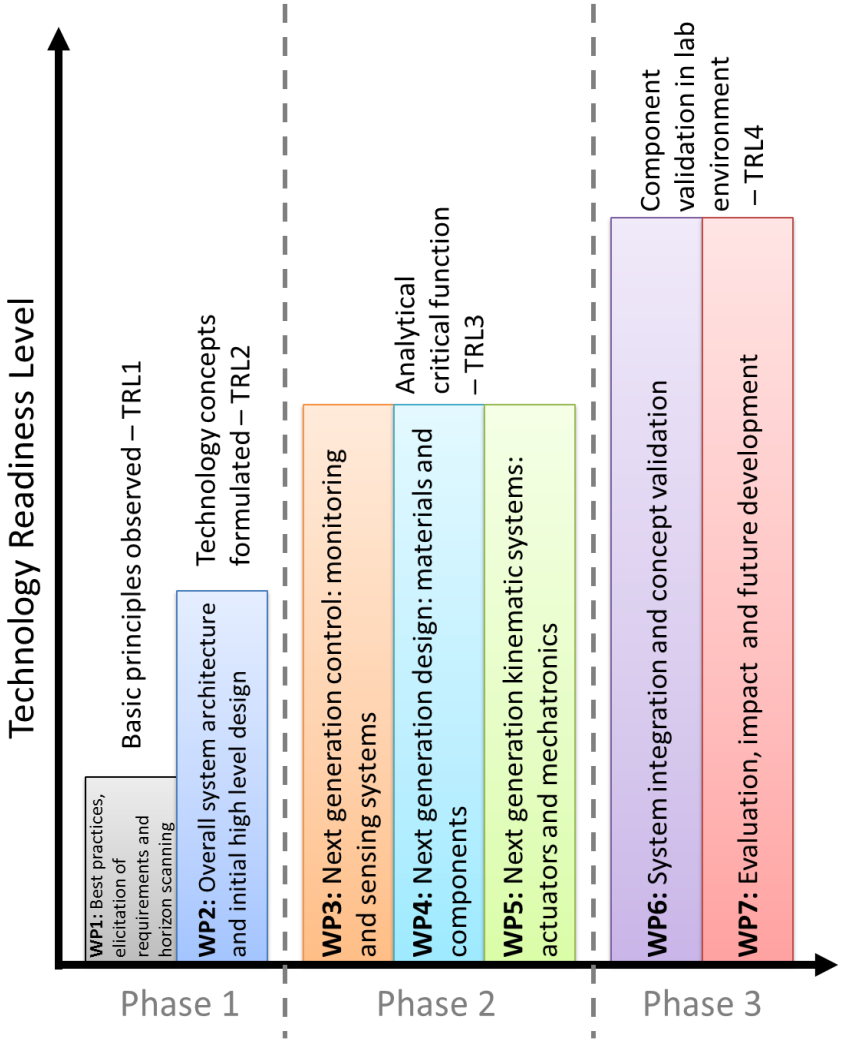
- Requirements and initial design

Phase 2 – Start May ’17

- Technical development

Phase 3 – Start Sept ’18

- Demonstration and evaluation



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Key challenges (from the S2R call)

- Wheel-rail interface optimisation (e.g. reducing/eliminating discontinuities)
- New switching function
- No in-service failures (self diagnostics, self correcting, self-heal)
- Reducing whole life cycle costs (towards maintenance free and degradation free)
- Ability to change S&C configuration during its life
- Improvements in capacity
- Reduced complexity

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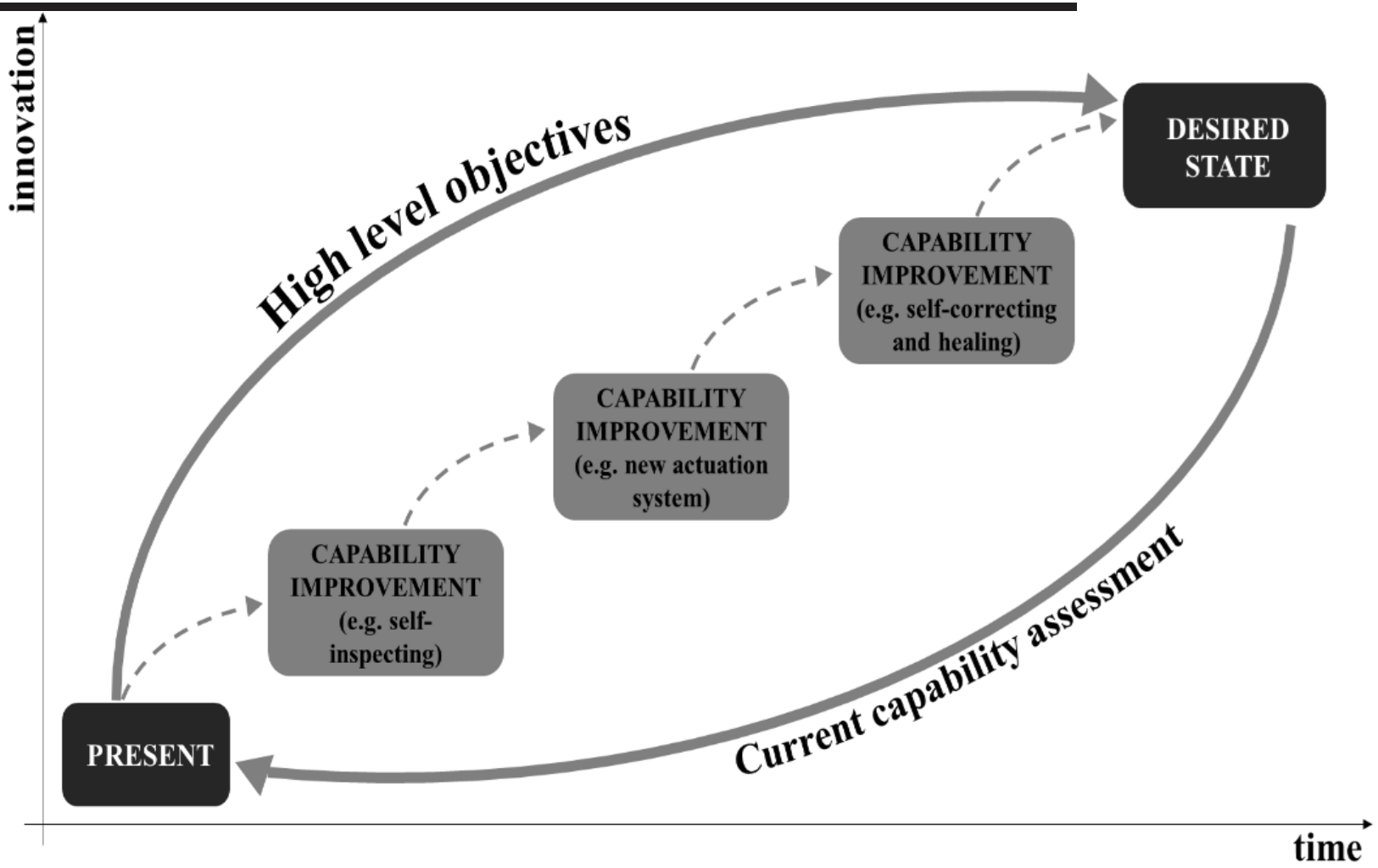
Thinking about the future



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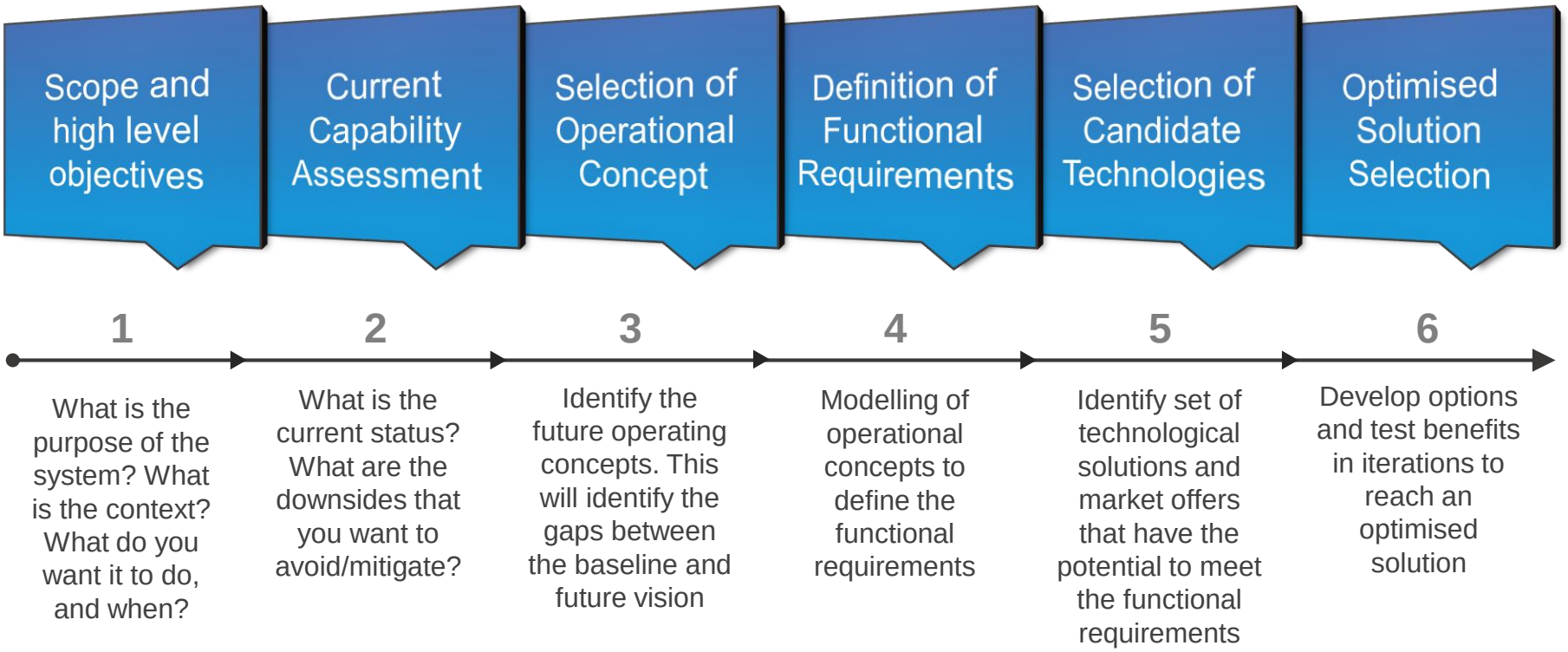
Method for radical change

DESIGNING FUTURE SOLUTIONS

A systems approach to backcasting



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Method for radical change

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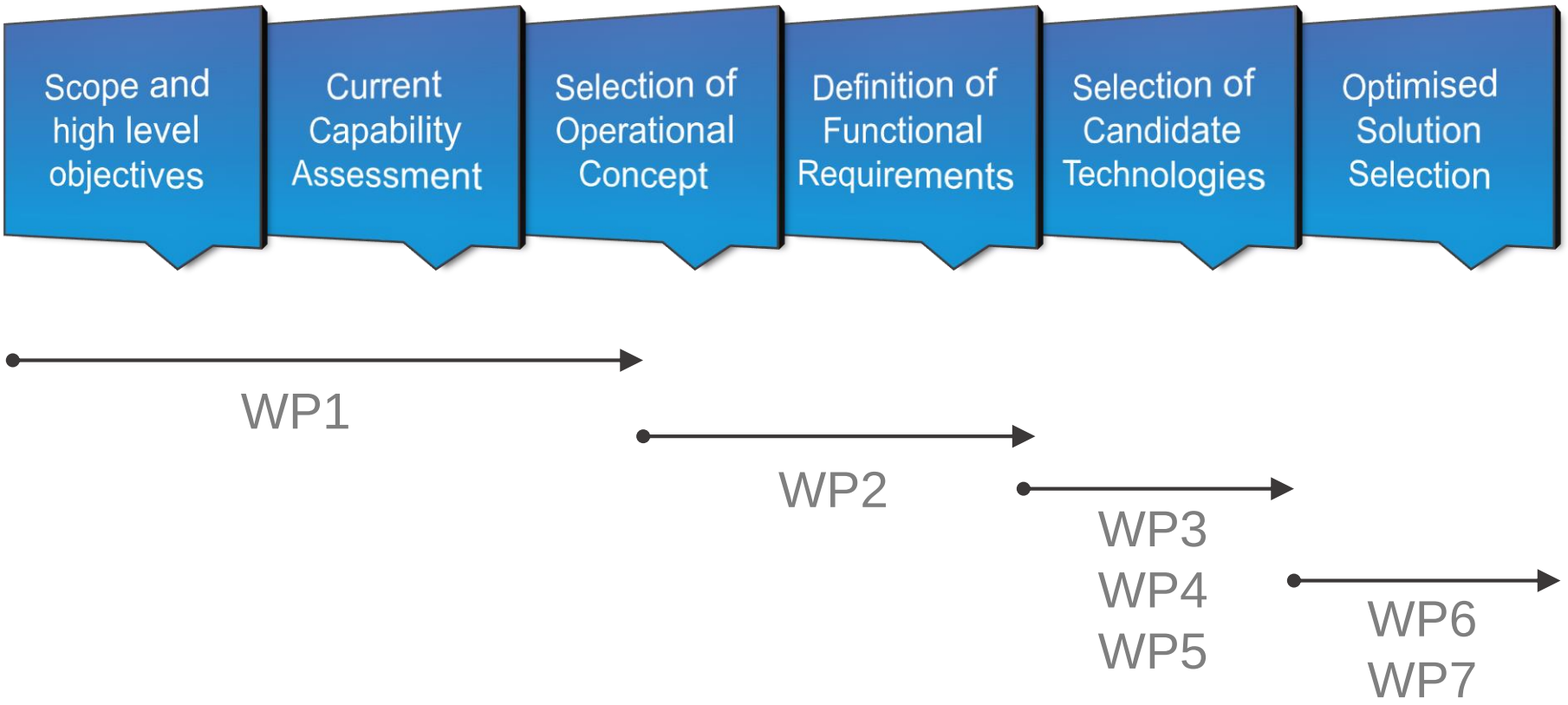

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Project relationships

- Drawing significantly from:
  - Innotrack (UoB, RSSB, BUT)
  - IN2RAIL (UoB, COMSA, L'boro)
  - Capacity4Rail (UoB, COMSA)
  - AUTOMAIN (UoB)
  - MAINLINE (COMSA)
  - … various national projects

- Working in parallel with:
  - IN2TRACK (UoB)
  - … various national projects

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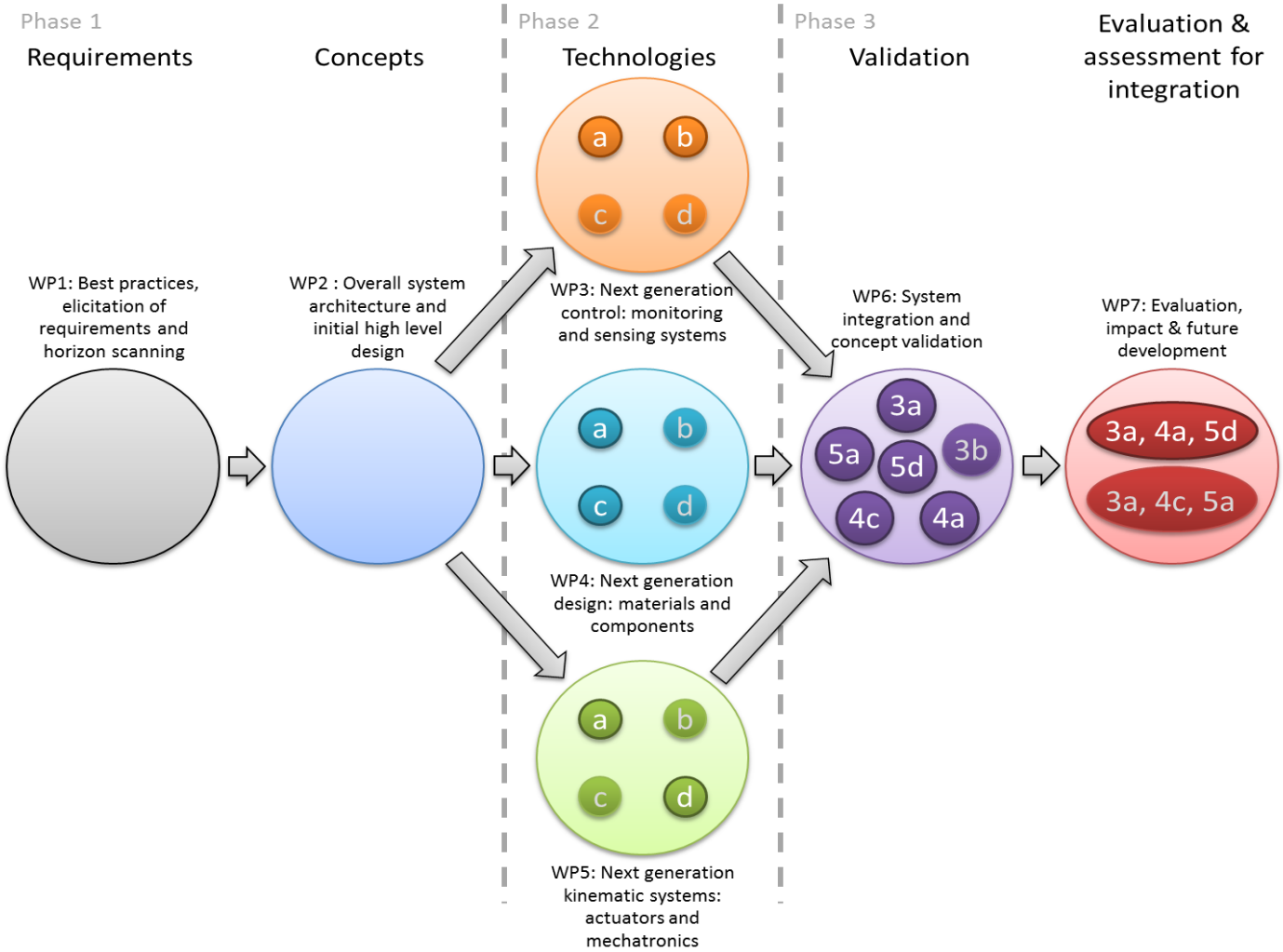
Overall Methodology



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Innovative approaches in S&C: Switzerland

- **RACK AND PINION SWITCH**

The spring switch is based on the idea of a "cut out" section of track, which acts as a kind of "spring" that is fixed at one point and bends from one end position to the other, along a precisely defined curve.

In the end positions, the system operates like a "closed" track.

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Innovative approaches in S&C: Switzerland (Dolderbahn)

Innovative approaches in S&C:
Switzerland (Pilatus Railway)

Innovative approaches in S&C:
Switzerland (Pilatus Railway)

Innovative approaches in S&C: The Netherlands

- **Winterproof Railway Turnout:** This new design turnout is not fitted with horizontal movable tongues, and because of that, snow and ice have no impact on the correct working of the turnout. Therefore, it needs no turnout heating at all.

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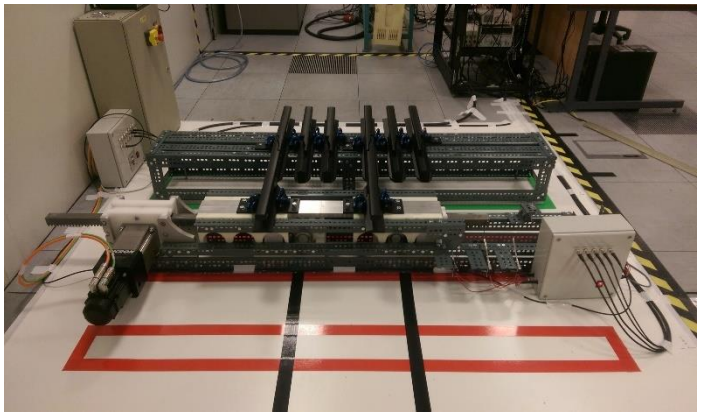
Innovative approaches in S&C: USA (Mount Washington Railway)

Innovative approaches in S&C: UK

- Repoint



- Work on In2Rail

  (incl. HPSS switch and use of feedback)

- Autochock
  - Stretcher bar failsafe lock to overcome run through problems associate with non-trailable switches

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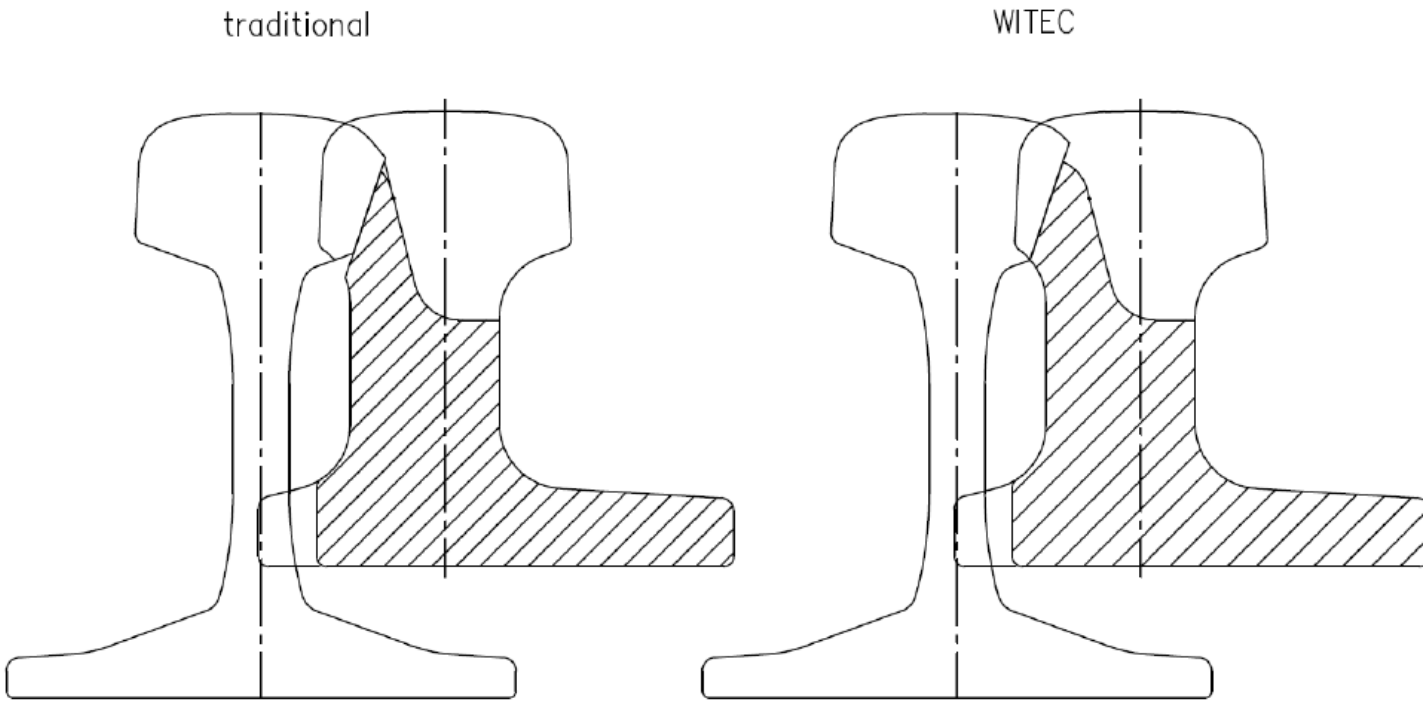
Potential Innovations: Improve Guiding Kinematics



The new design is based on two different milling angles (as the previous just was a straight line). The improvement leads to that the first wheel/rail interaction point occurs where the switch blade is thicker. A second change is that the gauge was changed to 1437 mm instead of 1435 mm. The latter change should give a lower lateral impact on the switch blade at the transition zone.

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Potential Innovations: Removable contact surfaces

Save on both the cost of manufacture and replacement.

The component can be refurbished easily by replacing the contact surface, retaining the majority of its original material and installation.

This principle may be difficult to apply to existing switch rails due to their reduced and variable profile, existing stock rails, crossings and wing rails may be better candidates.

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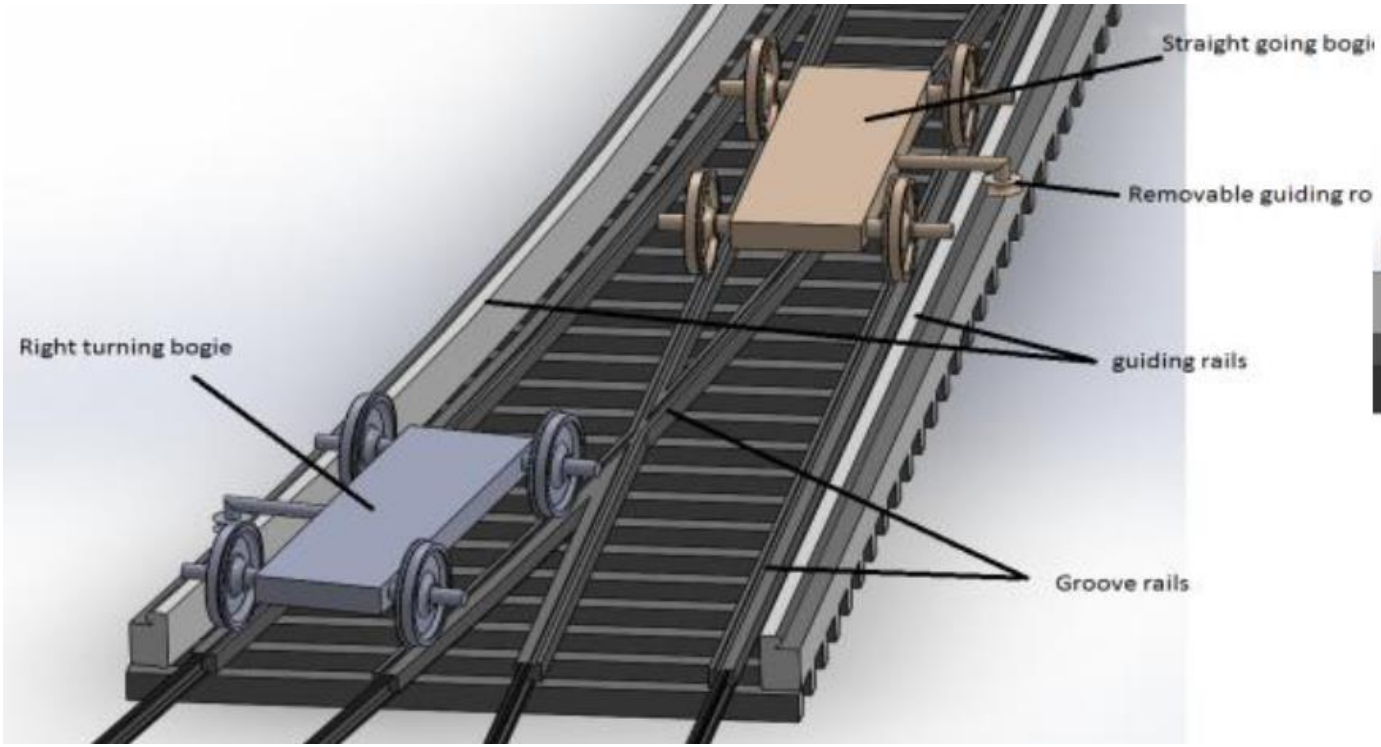
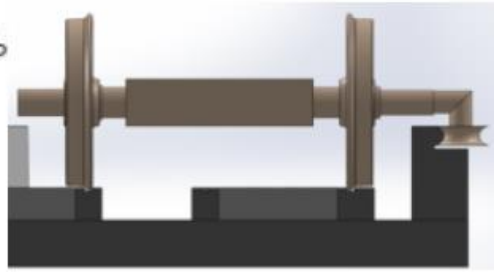
Potential Innovations: Passive infrastructure: separate steering rails





Cross section of the idea, showing the two separate wheel-rail interfaces.

The steering function is achieved by guiding rails situated on either side of the track, which interface to removable rollers located on the vehicle. Many rollers may be necessary, maybe one per bogie or even one per wheelset. When required, the rollers are moved into position on the correct side of the vehicle for the desired route.

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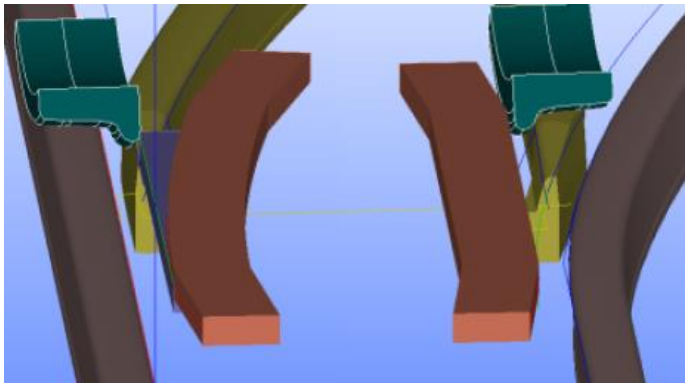
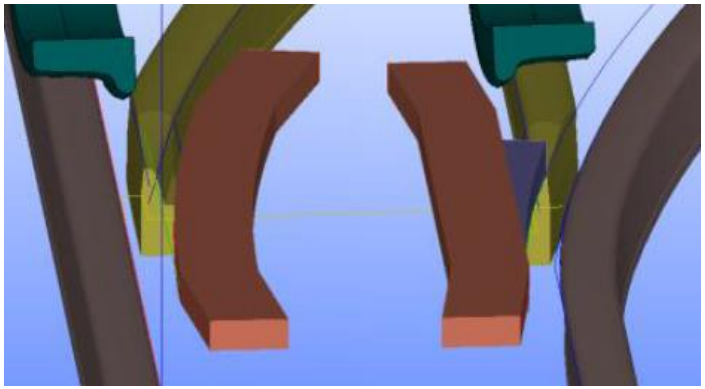
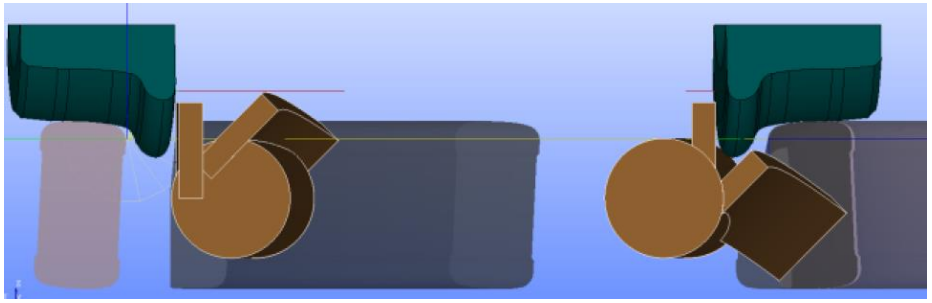
Potential Innovations: Flange-back steering







Flange-back steering (FBS) differs from the conventional method in guiding the back of the wheel flange not the front. This isn't unusual; it is how wheels are guided through either of the two paths through crossings, but with FBS the paths are alternatives, actively switched, and the wheel load carrying is separated from the wheel guidance.

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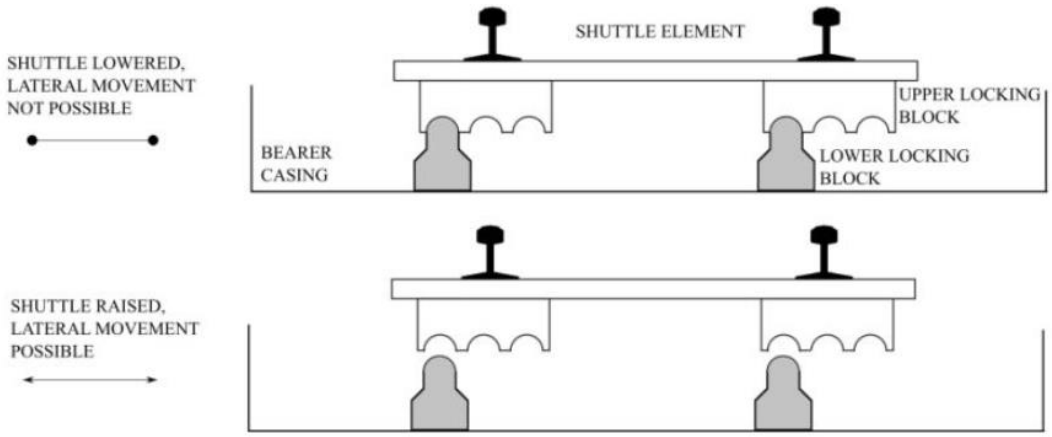
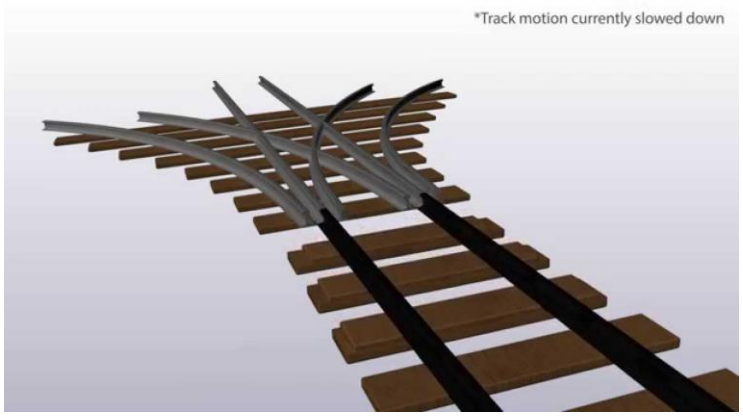
Potential Innovations: Hopping stub switch (REPOINT)





Actuation is provided by a multi-channel actuation bank, with the actuation elements contained within bearers near the movable rail ends. The Idea Diagram below shows the general arrangement of a 'Repoint' stub switch. Numbered elements as follows; (1) In-bearer type electromechanical actuators featuring integral passive locking and detection systems; (2) Bearer featuring integral passive locking elements; (3) Bendable, full-section switch rails; (4) Interlocking rail ends. Triplex redundancy is shown, with each actuator/bearer being capable of moving the switch alone.

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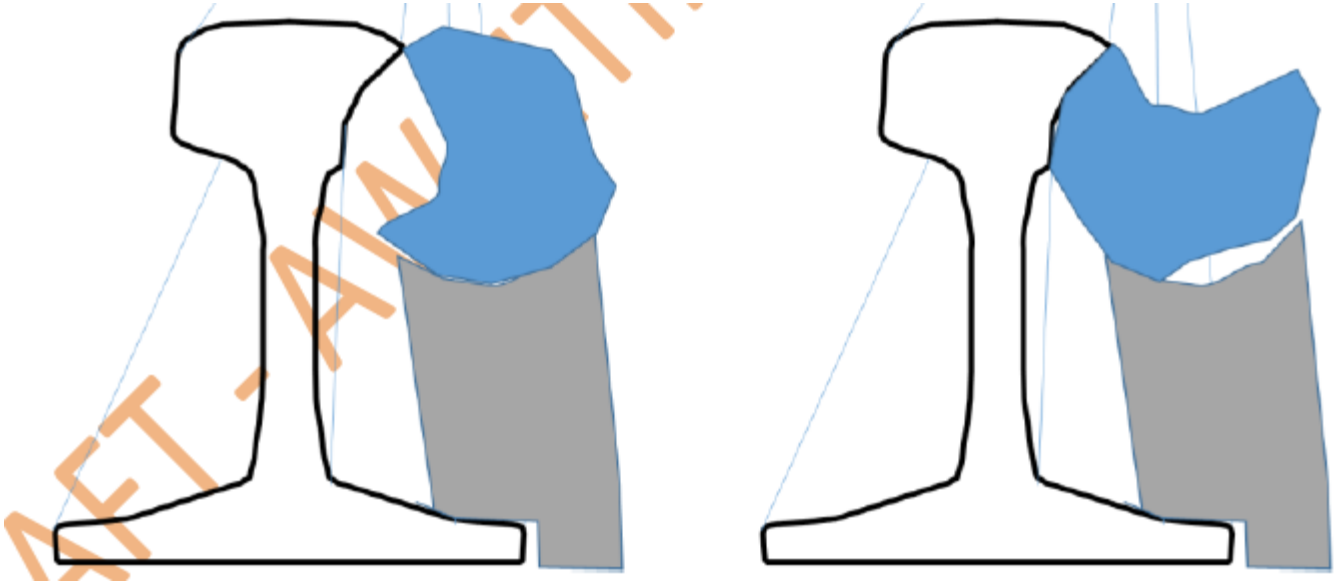
Potential Innovations: Rotating Switch Rail



The transition between the stock and switch rail is replaced with a rotating element. The appropriate profiles to guide the vehicle in either the through or diverging routes are machined into opposing sides of the bar. The same approach could be applied at the crossing in place of a swing nose design.

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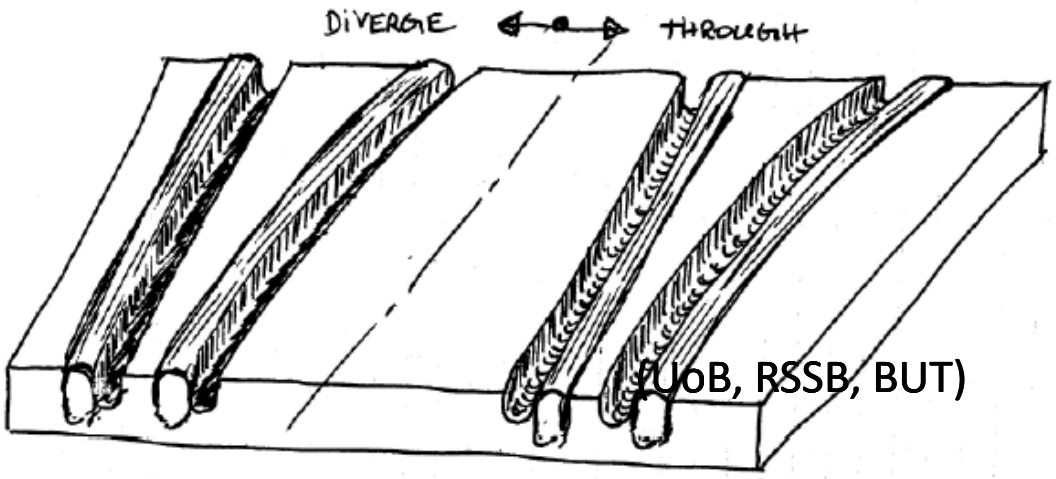
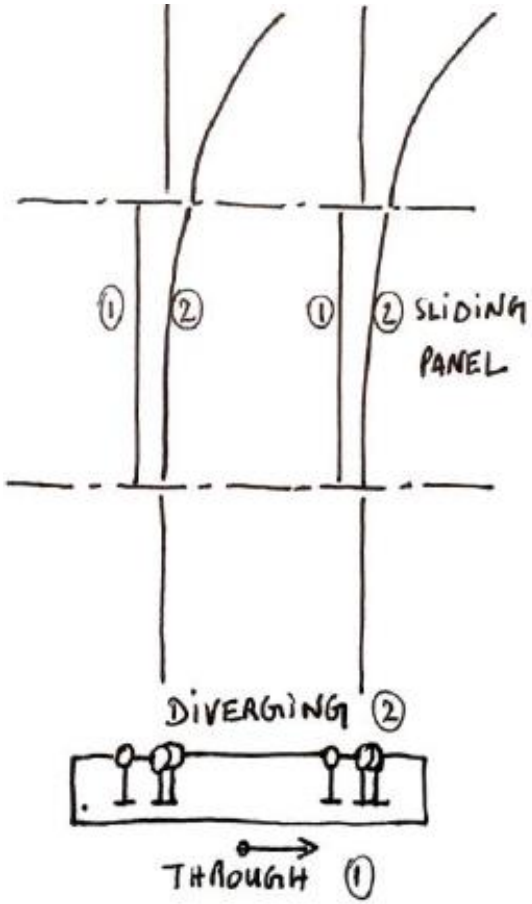
Potential Innovations: Multi path panel



(UoB, RSSB, BUT)



The panel can slide into at least two fixed positions to assume either diverging or through route activation. The entire 'panel' sits within a "clean environment" principle for optimal performance and minimal maintenance and human intervention.

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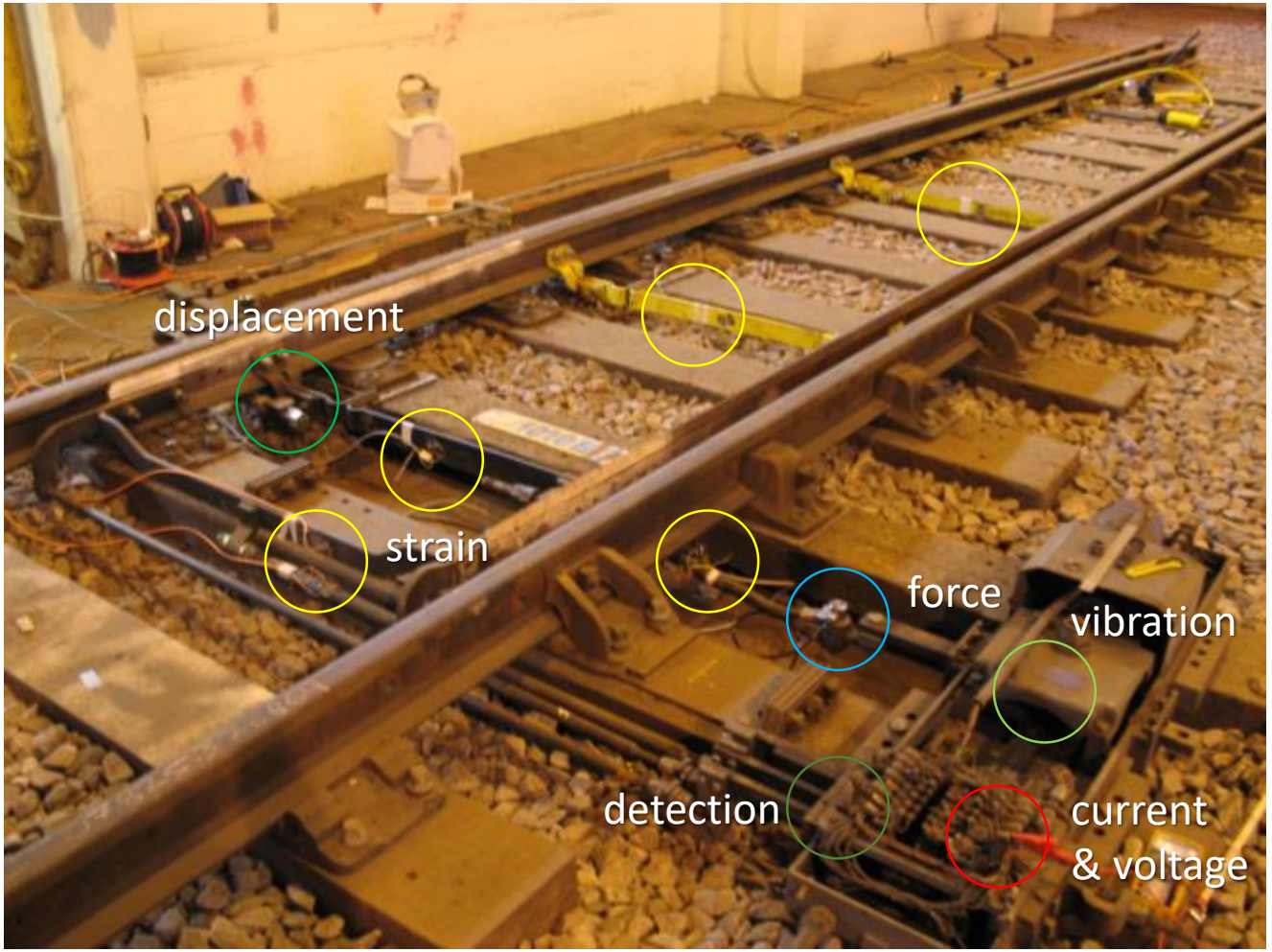
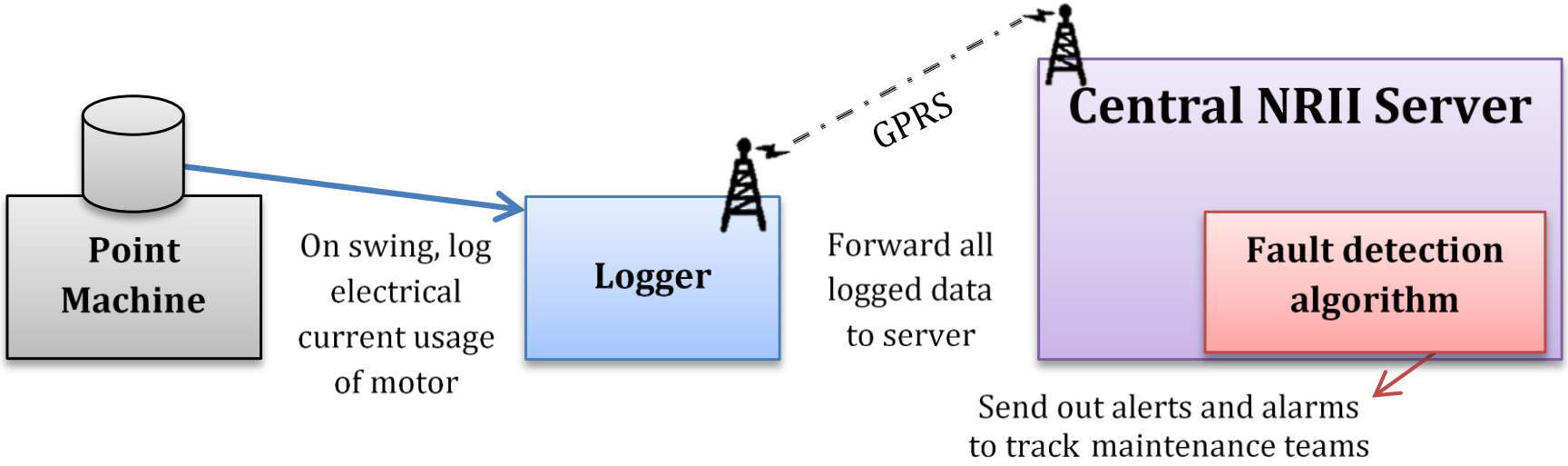
Instrumentation Innovation

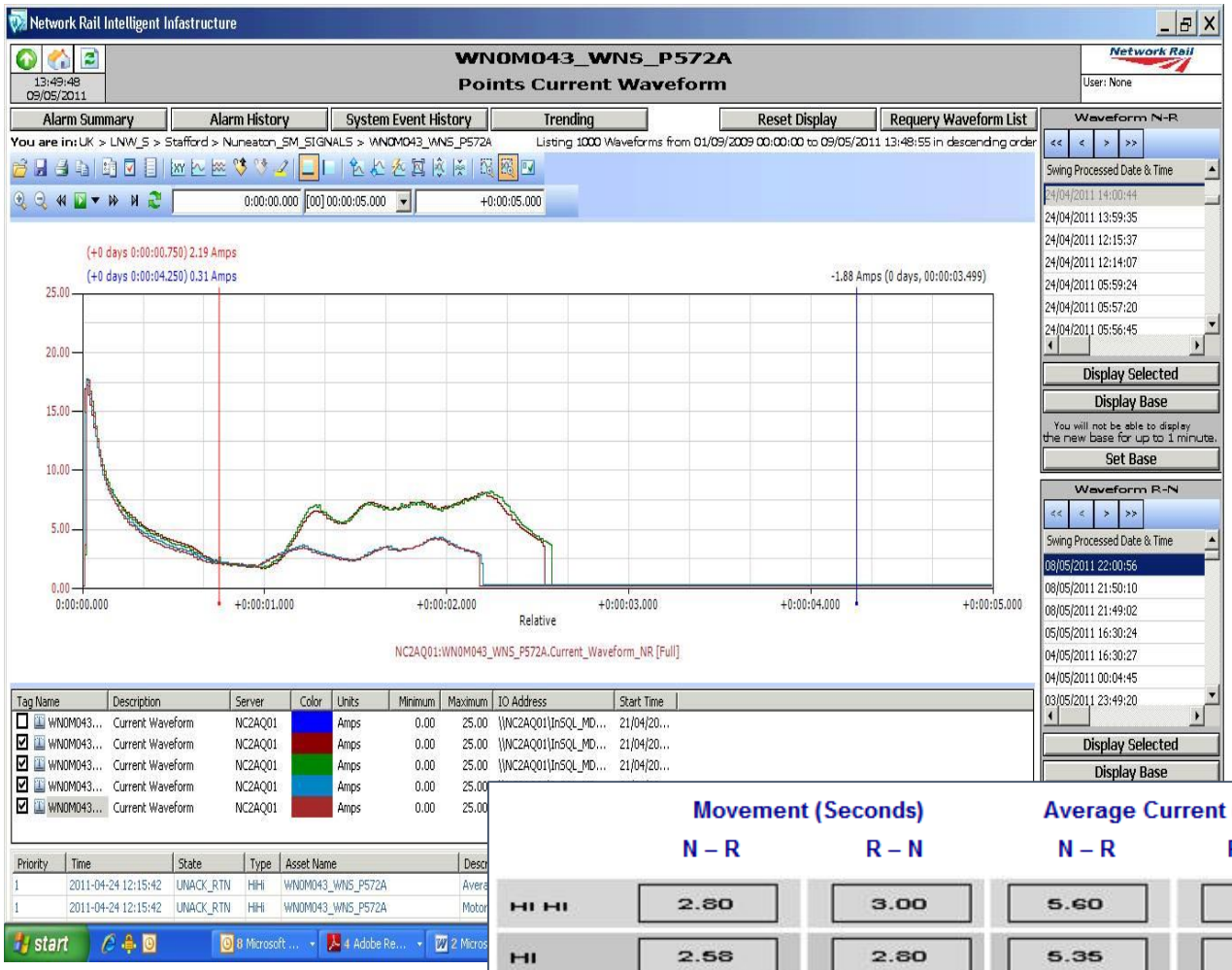


Potential Instrumentation: UK PCM infrastructure

- Points condition monitoring infrastructure exists in the UK on thousands of points
- Monitors point machine current at 100 samples per second and transmits via GPRS link to central server
- Basic thresholds trigger alarms



Potential Instrumentation: UK PCM infrastructure

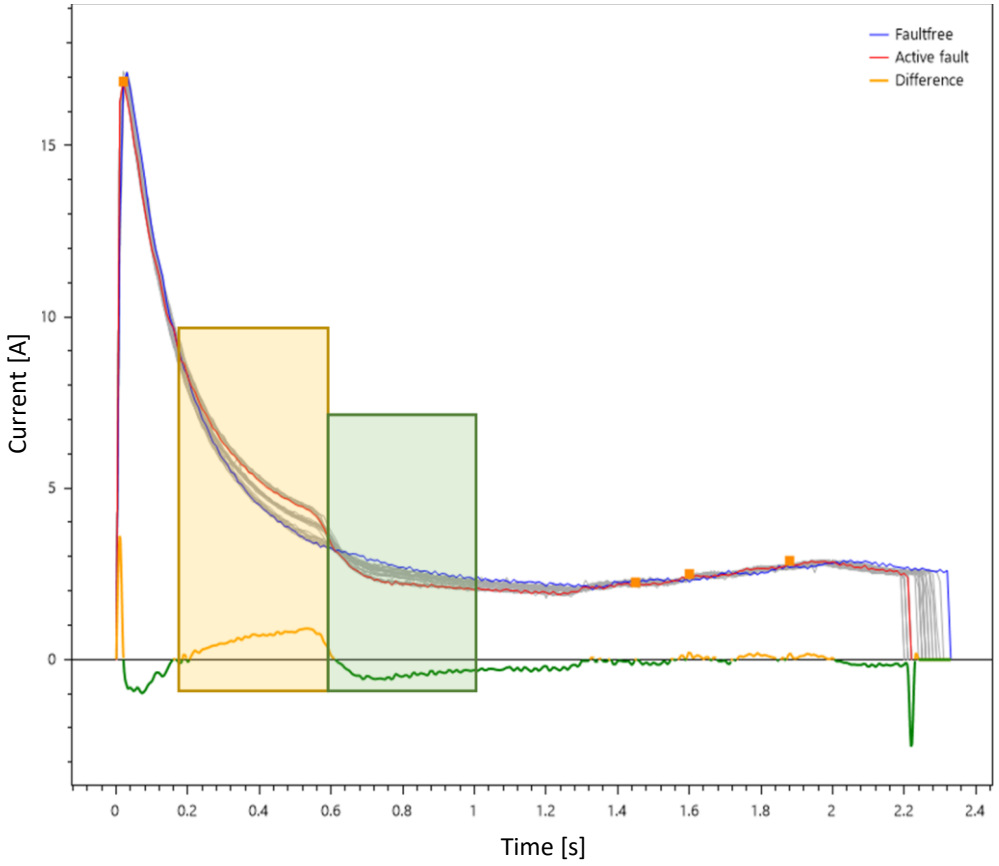


	Movement (Seconds)		Average Current (Amps)		Peak Current (Amps)	
	N – R	R – N	N – R	R – N	N – R	R - N
HI HI	2.60	3.00	5.60	5.60	30.00	30.00
HI	2.58	2.80	5.35	5.35	25.00	25.00

Potential Instrumentation: UK PCM

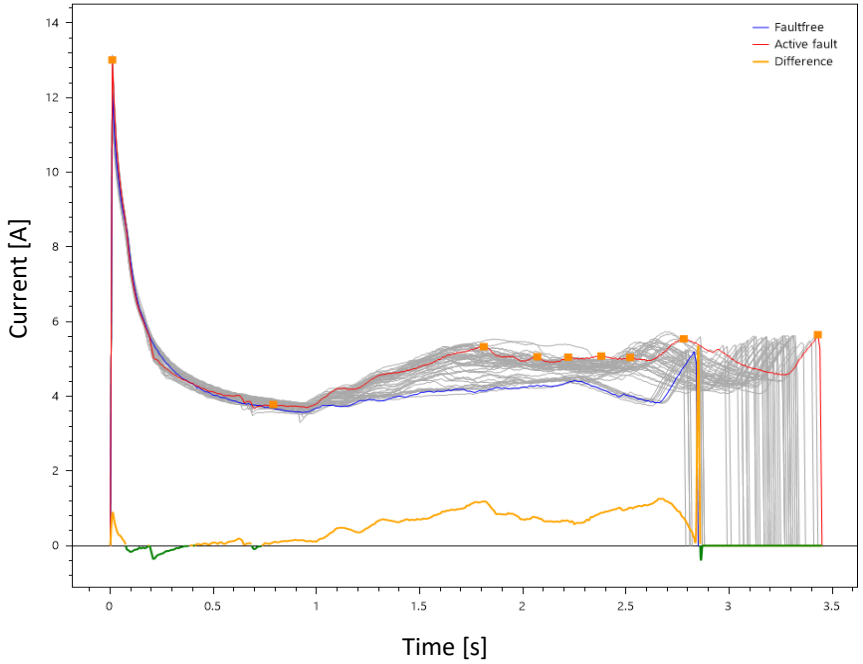
Enhanced PCM (ePCM)

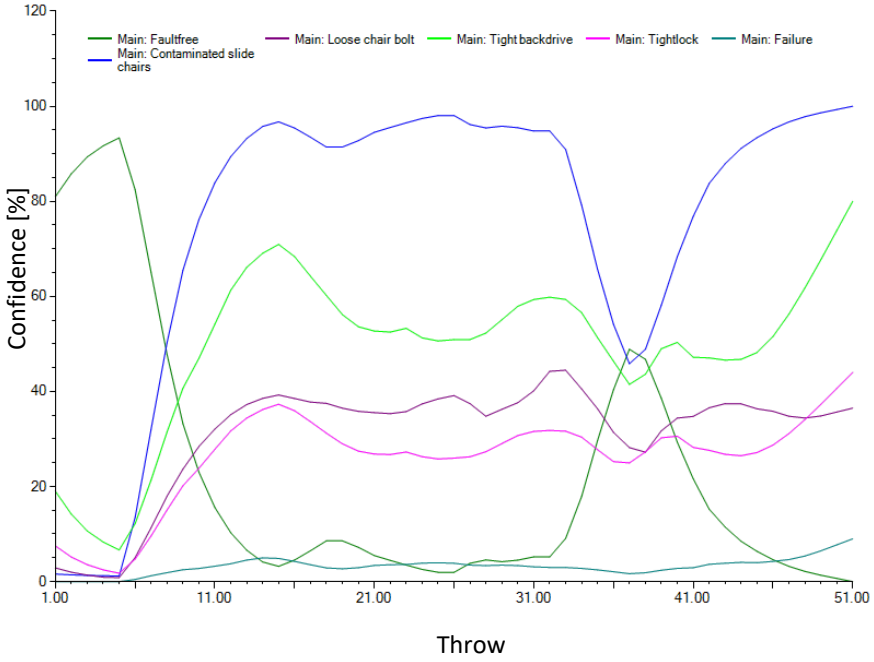
- Fault detection
  - Detect presence of fault
  - Completed
- Fault diagnosis
  - Identification of fault
  - Demonstrator
- Fault prognosis
  - Time to failure
  - More data required



Potential Instrumentation: UK PCM

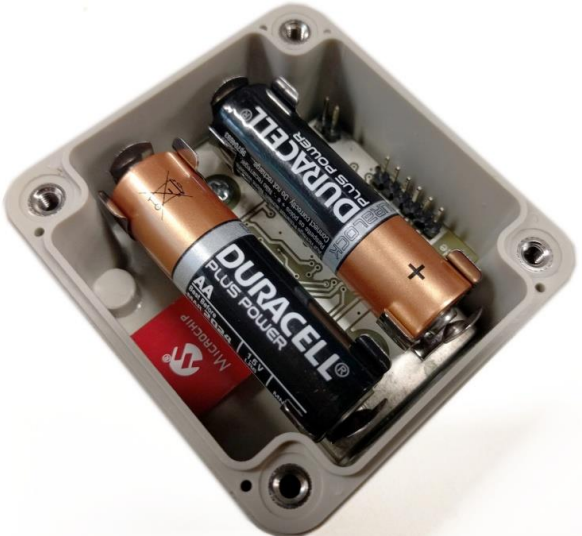
Detection of contaminated slide chairs in Clamplocks



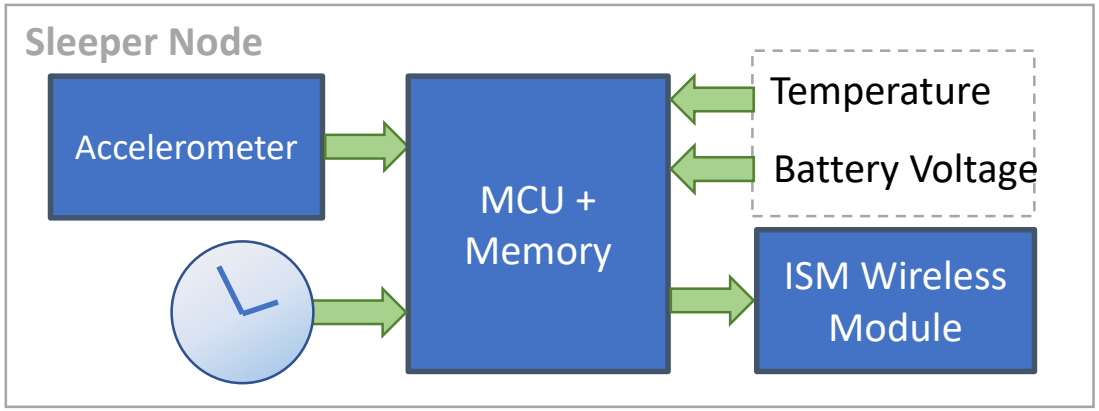


Instrumentation Innovation: Wireless nodes

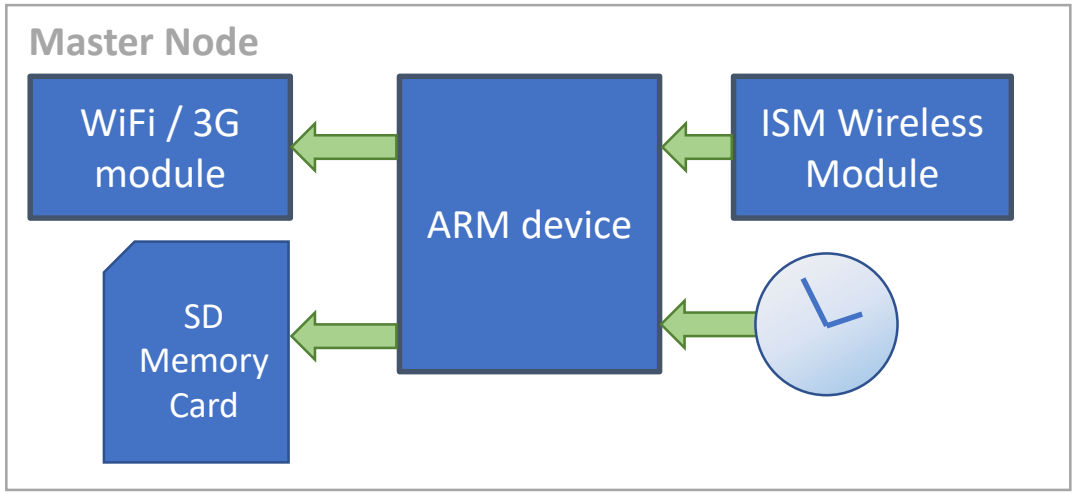
- Currently measuring sleeper accelerations
- Creation of *ad hoc* network
- The generic 'node' concept will evolve into a means of measuring long term settlement using lasers
- Can be deployed on a semi-permanent basis with no cabling requirements (and real-time data collection)



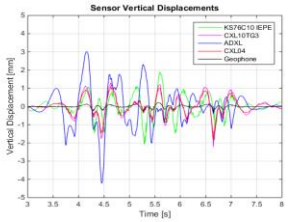
UoB Wireless Node System Overview

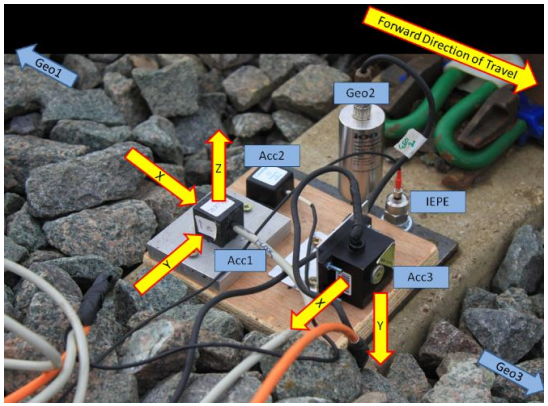


Low-power
Low-frequency
ISM band



Instrumentation Innovation: Trade-off in sensor quality



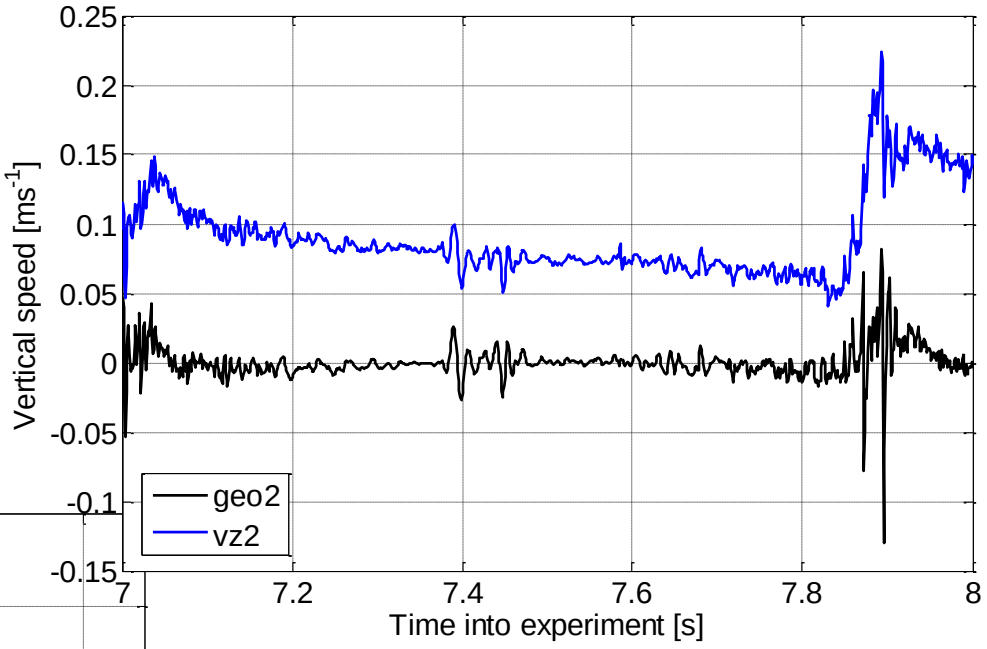


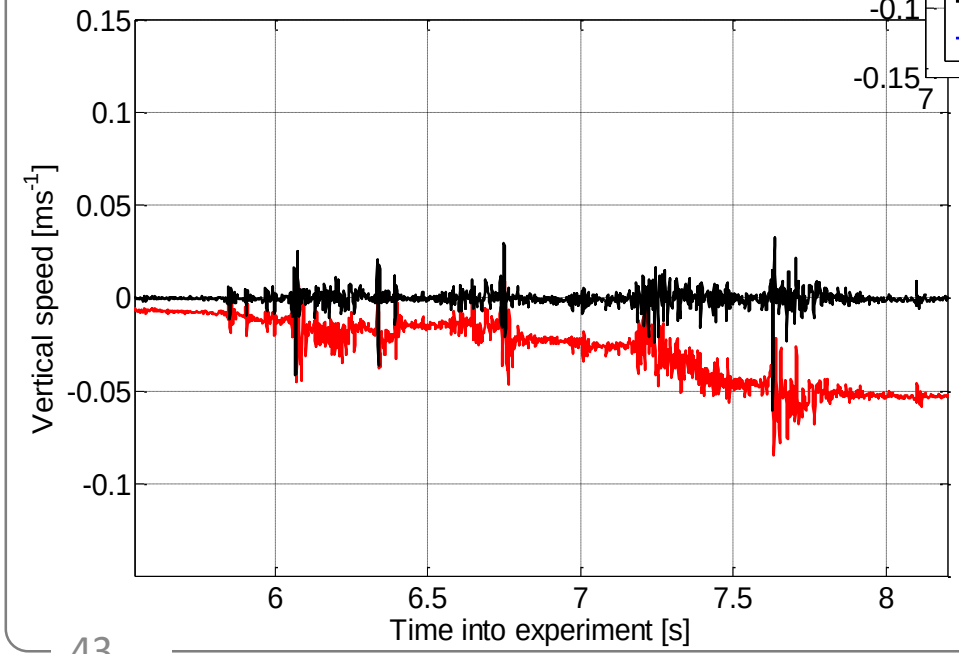
- Train travelling at 30 mph – N.B. this is too slow for good results
- Geophone has a smaller amplitude at this speed, but is likely to be the truest response (with shelving filter to reverse the natural high-pass filtering, then integrated and a high pass filter applied)
- Early generation ADXLs have poor agreement – we are using ADLX356 sensors now which appear to be much better (doubled integrated and then high pass filtering)
- CXL04 and CXL10 both have good agreement (doubled integrated and then high pass filtering)
- KS67 has a similar shape (doubled integrated and then high pass filtering)

Sensor Evaluation / Comparison

High quality (cost) sensor displays reasonable correlation

Key sensor attribute is stability for this application





Lower quality (cost) sensor displays significant drift

Also may be affected by significant events in the signal

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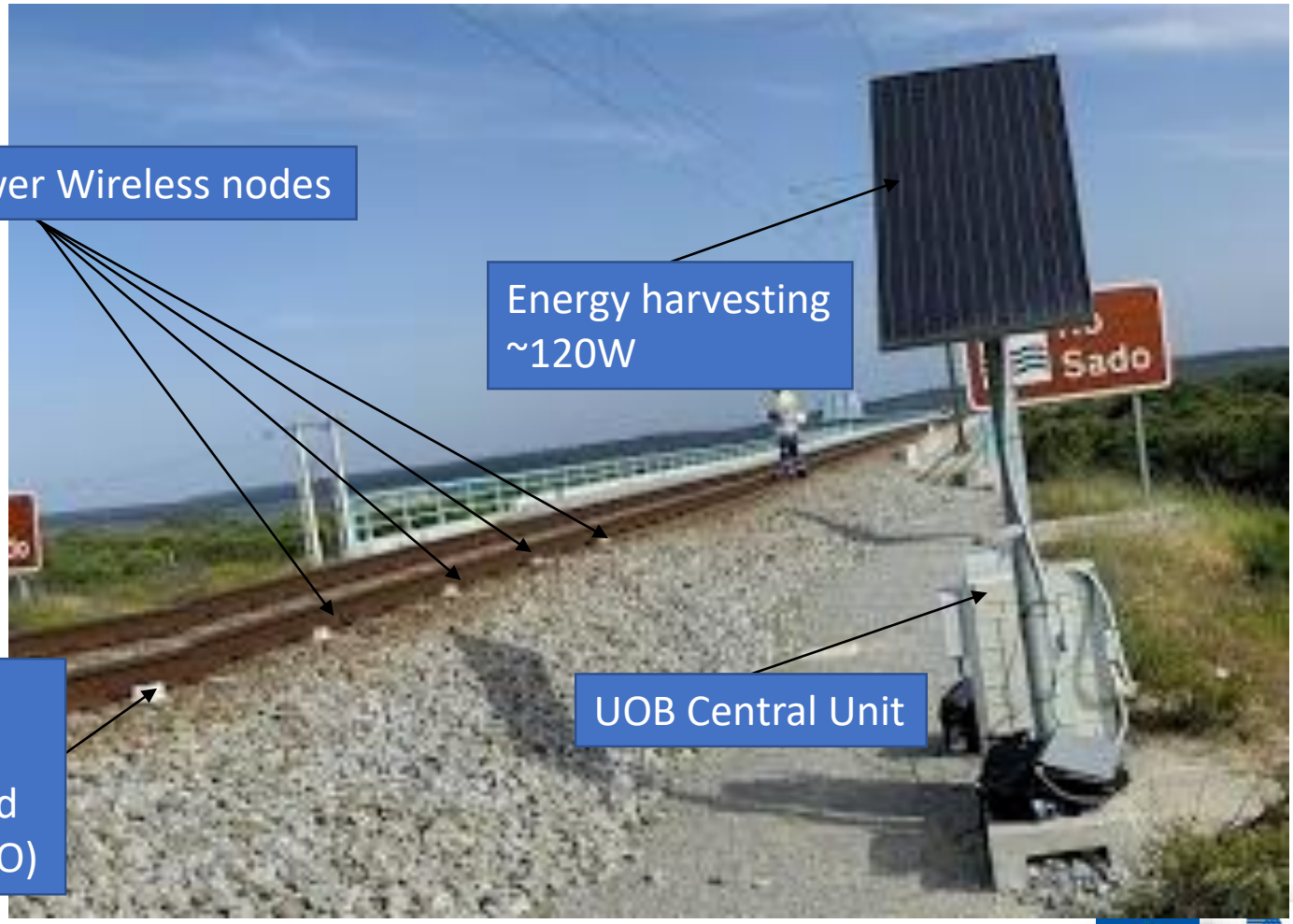
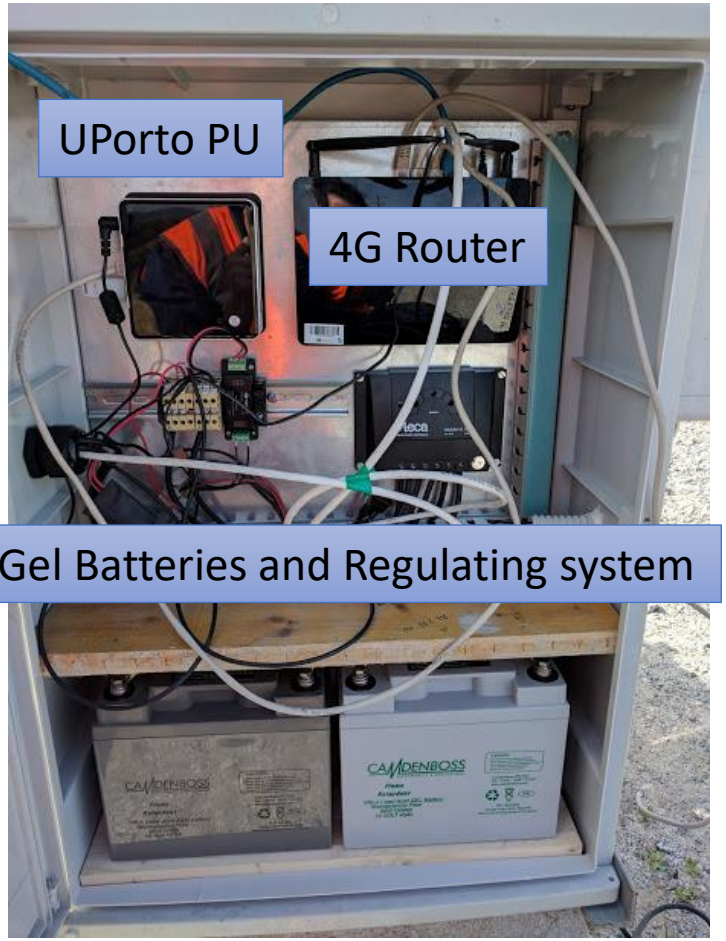


Alcácer do Sal

Main control panel



UPorto Vibration Node

UoB Central PU

UoB Vibration Node

UoB - Live Trial Initial Testing

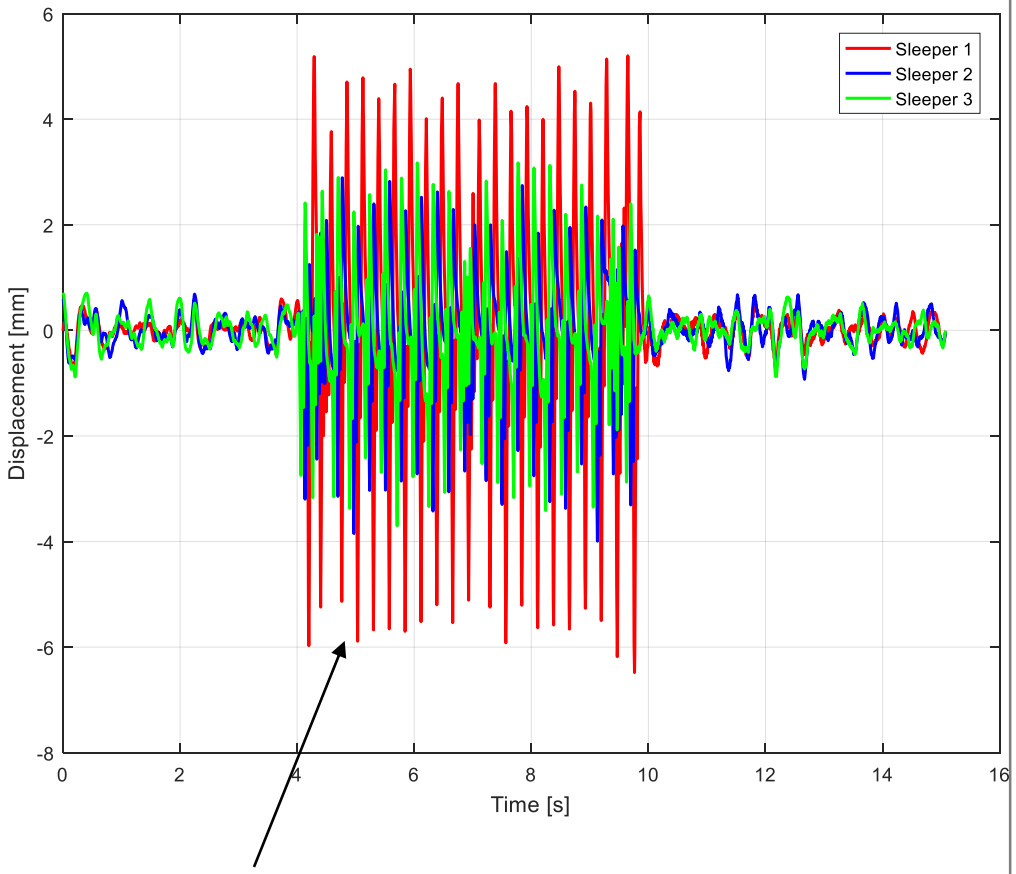
- 3 accelerometers installed on the UK HighSpeed 1 line
  - Line speed

    220 kph to 300 kph

- Around 1400 train passages were recorded over a 2 week period

Data Analysis - Accelerometers

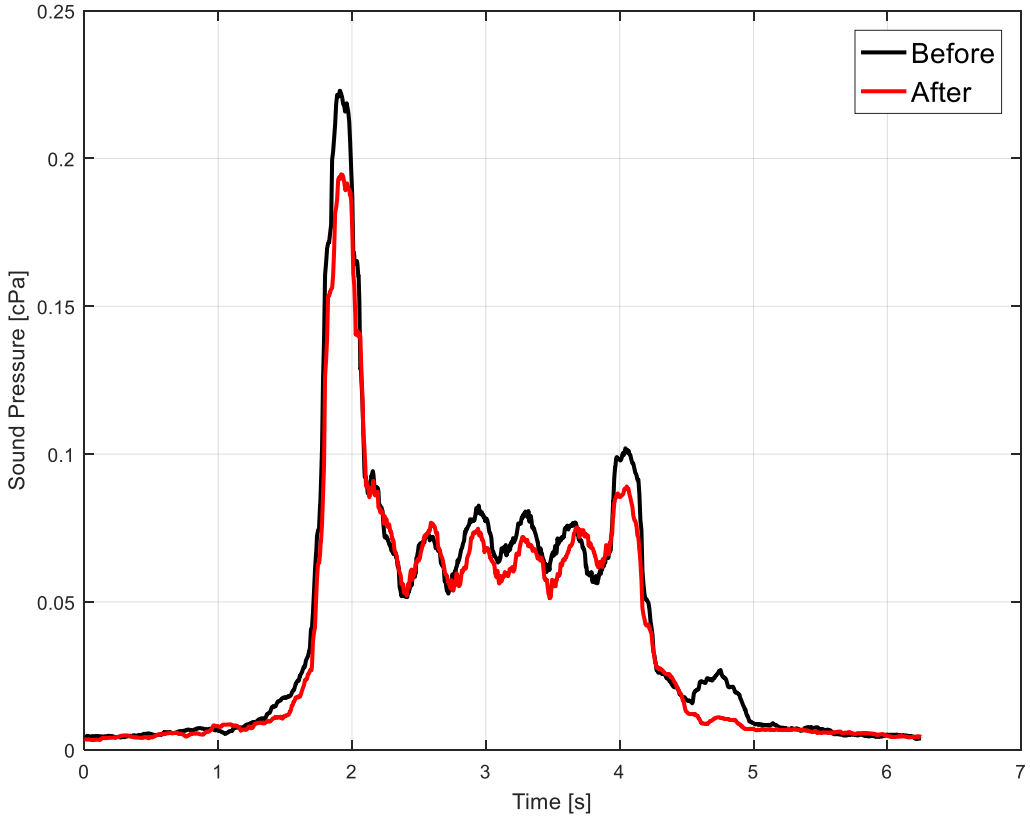
- Displacement curves for the three accelerometers
- One is significantly larger than the other two



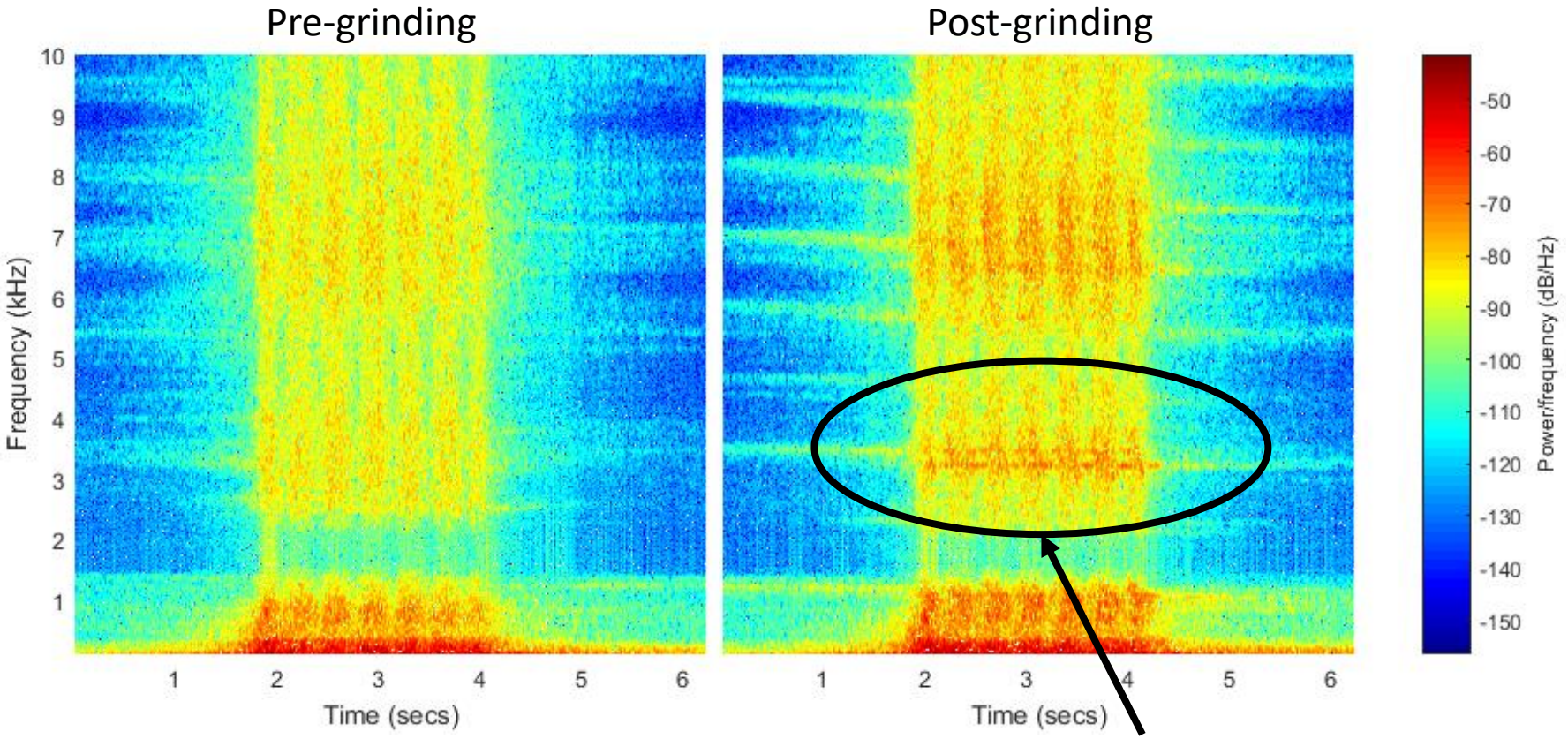
Less-well supported sleeper

Data Analysis – Sound Pressure

- Before and after rail grinding
- Lower RMS values in the sound pressure level after grinding



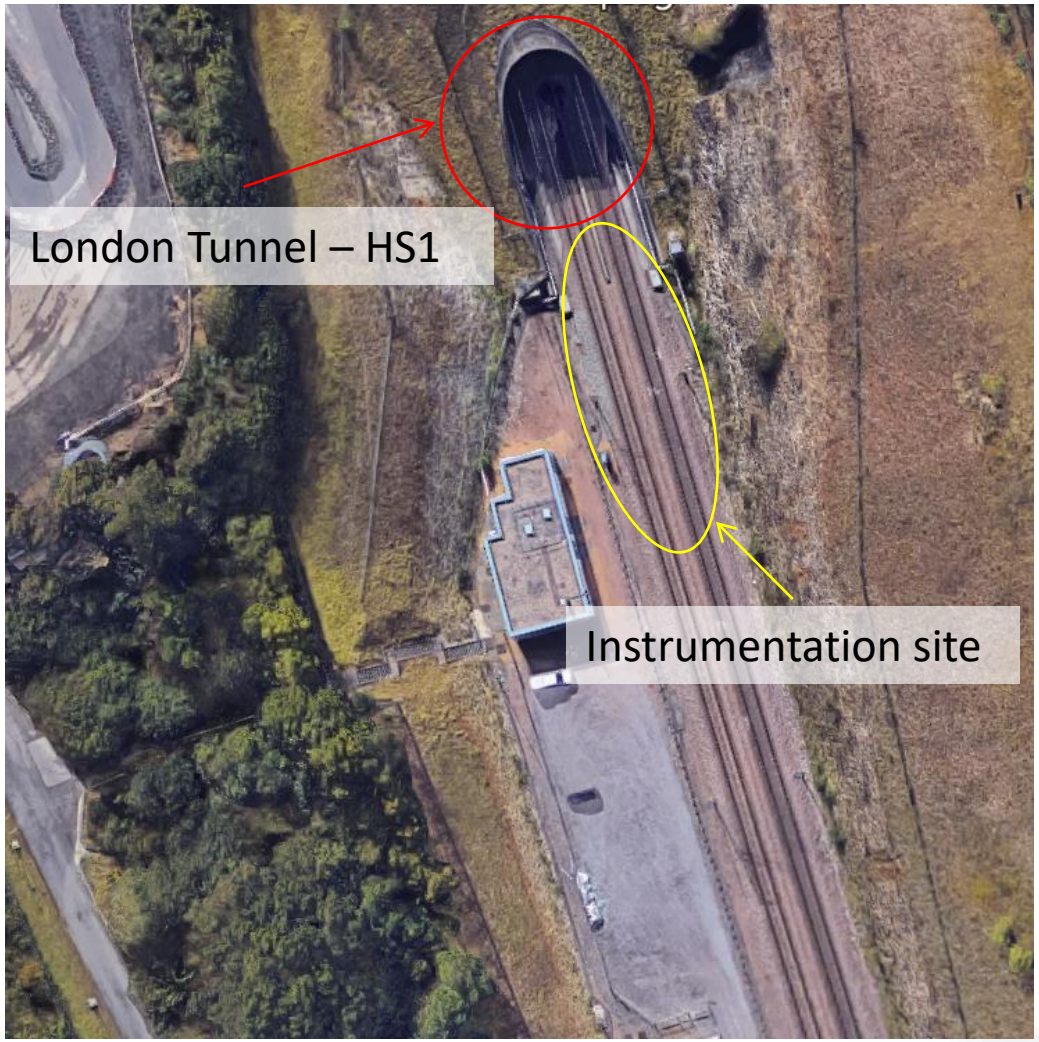
Rail Grinding – Sound Pressure



- Overall level slightly reduced (<3dB)
- Noise distributed over wider frequency range
- Some wheel / rail effects to be considered

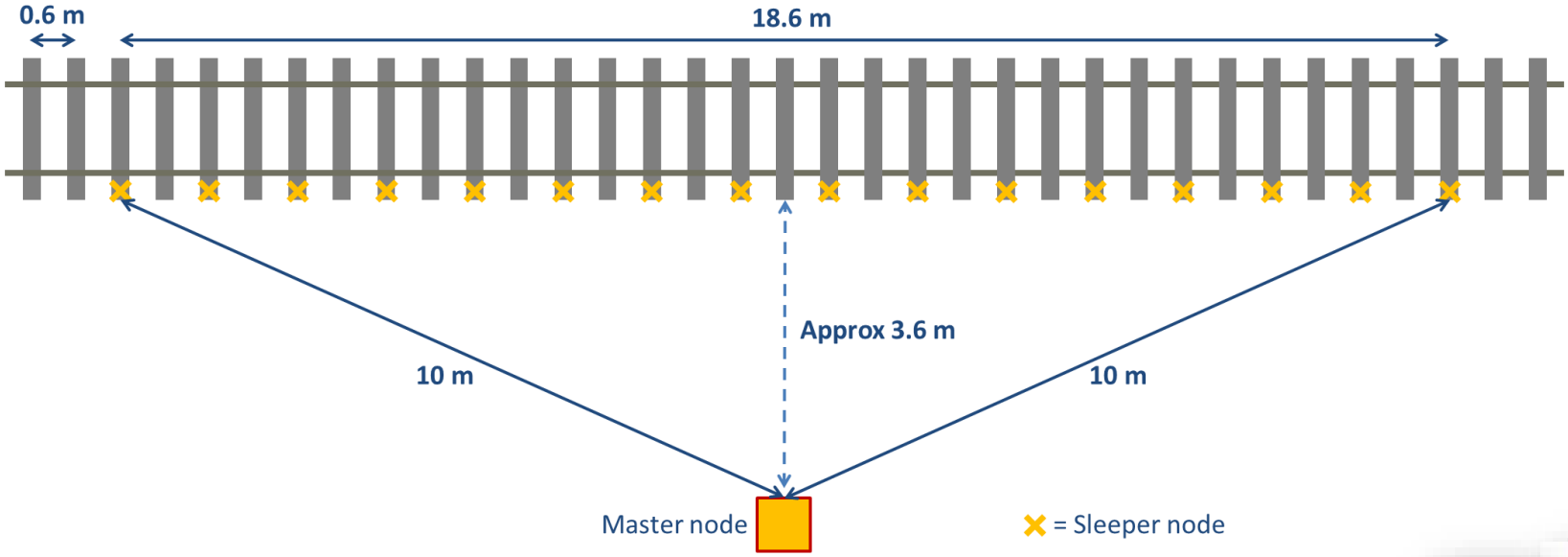
UK Instrumentation Site

- High-speed 1 track
- Area of interest to Network Rail
- Multiple instrumentation types
  - Vibration
  - Acoustic
  - Speed
  - Visual
  - Thermal
- Proximity to NR Gotcha site
- Aligned with on vehicle measurements
- Known train IDs
- Easy access



Instrumentation Plan

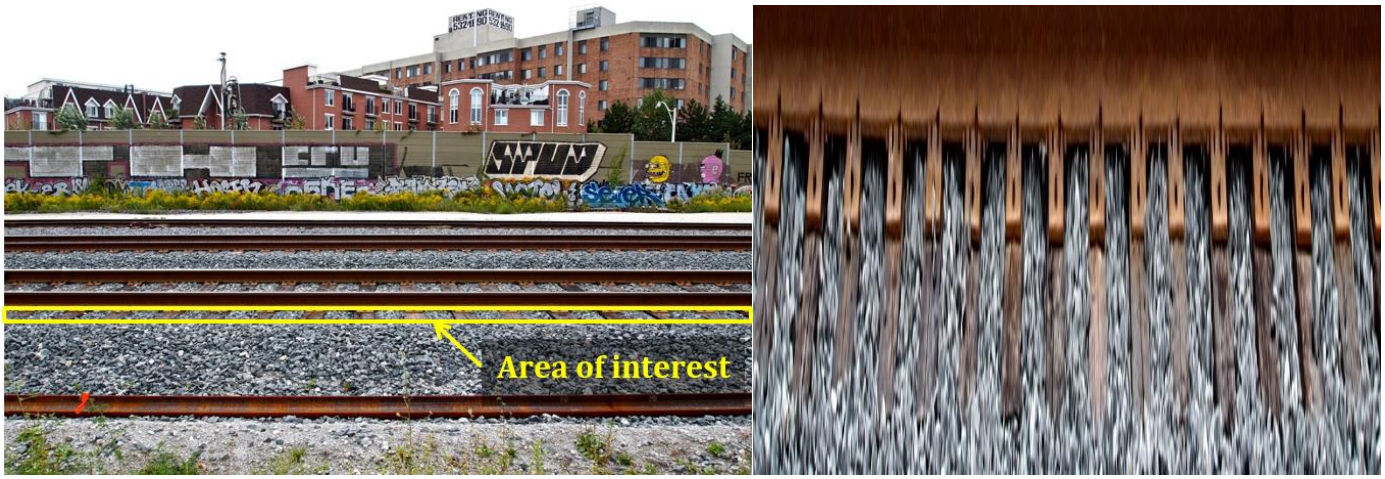
- 16 wireless nodes
  - 14 battery powered
  - 2 solar panels and battery
- Vibration and temperature monitoring
  - Lateral acceleration - 4 nodes
  - Vertical acceleration – 12 nodes



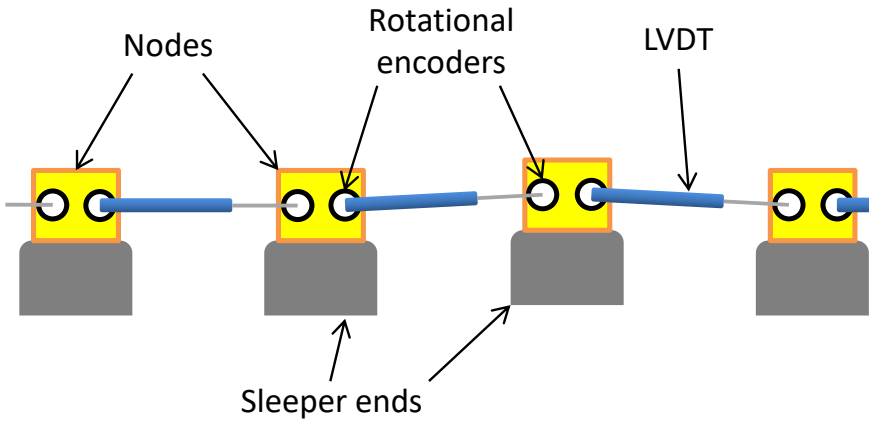
Instrumentation Innovation: Absolute settlement

- Review of possible approaches:

Camera based



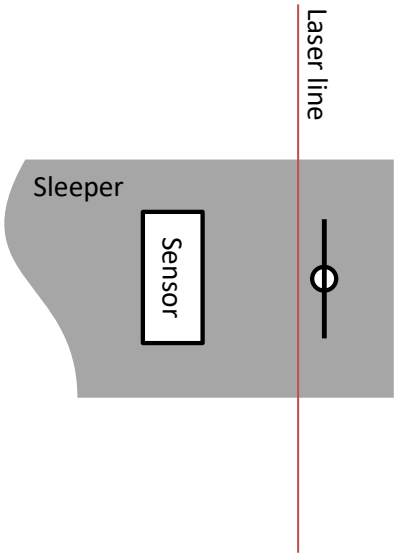
Mechanical

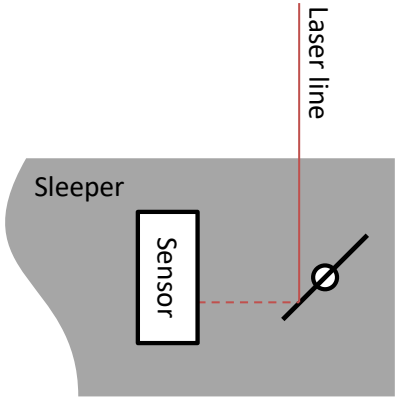


Instrumentation Innovation: Absolute settlement

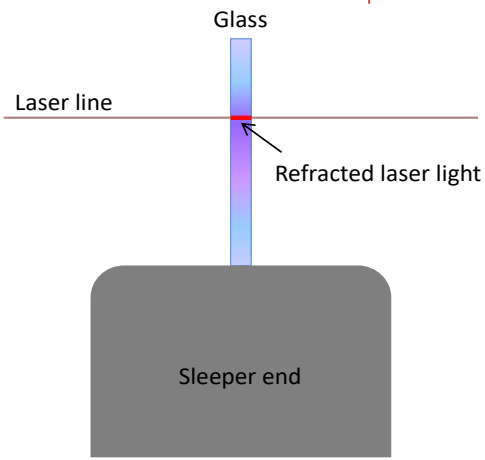
- Review of possible approaches:

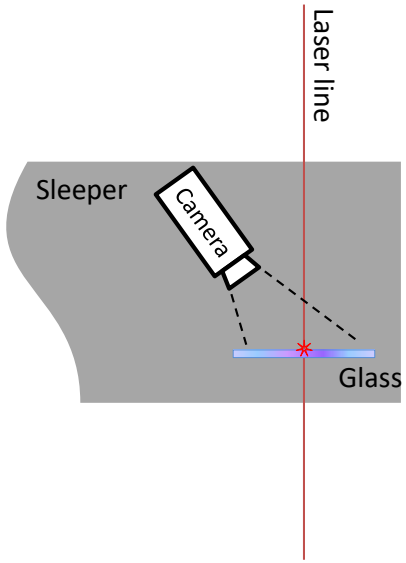
Laser with moveable shutter





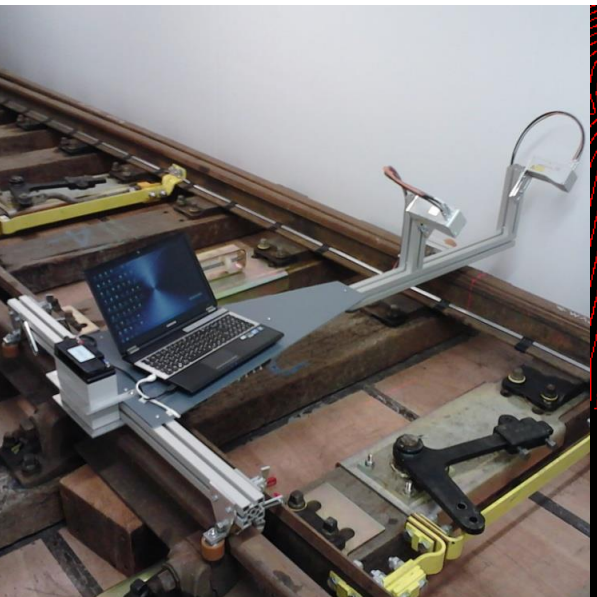
Laser refraction

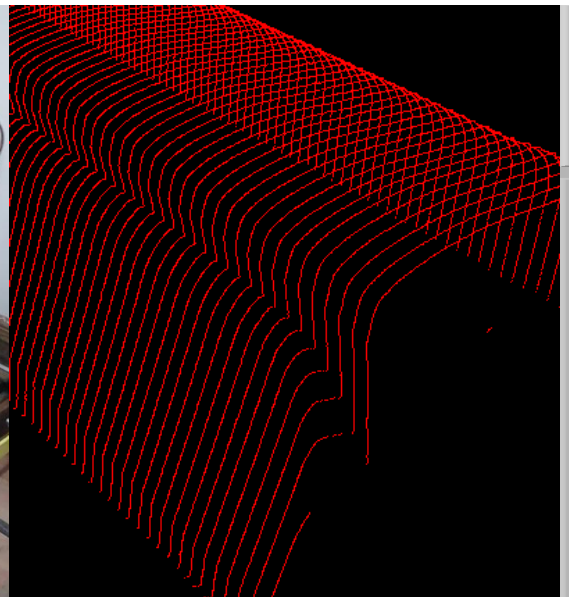


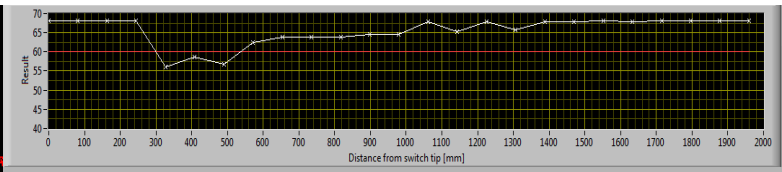


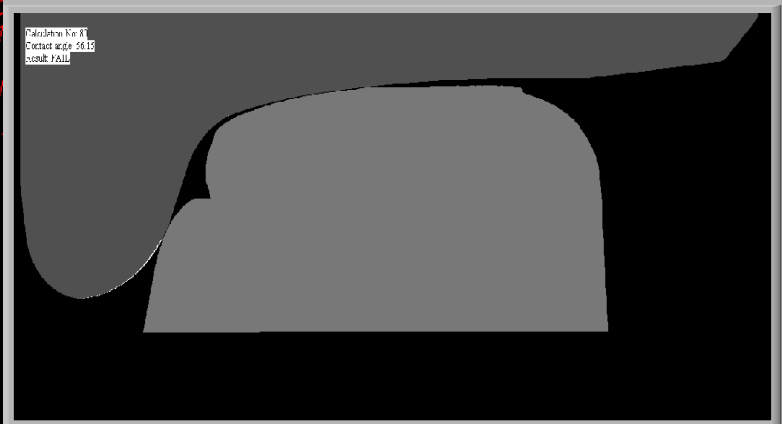
Instrumentation Innovation: Switch and crossing geometry

- Developed over several years at B’ham
- Many switches and crossing tested at Whitemoor Rail Recycling Centre and at Oxley deport
- Recently modified our existing trolley switch measurement trolley to include blue lasers (for improved day time performance)
- Automated testing of Network NR/L2/TRK/0053 testing standards
- A parallel stream is developing a productised version through a KTP with Abtus (with support from Network Rail)

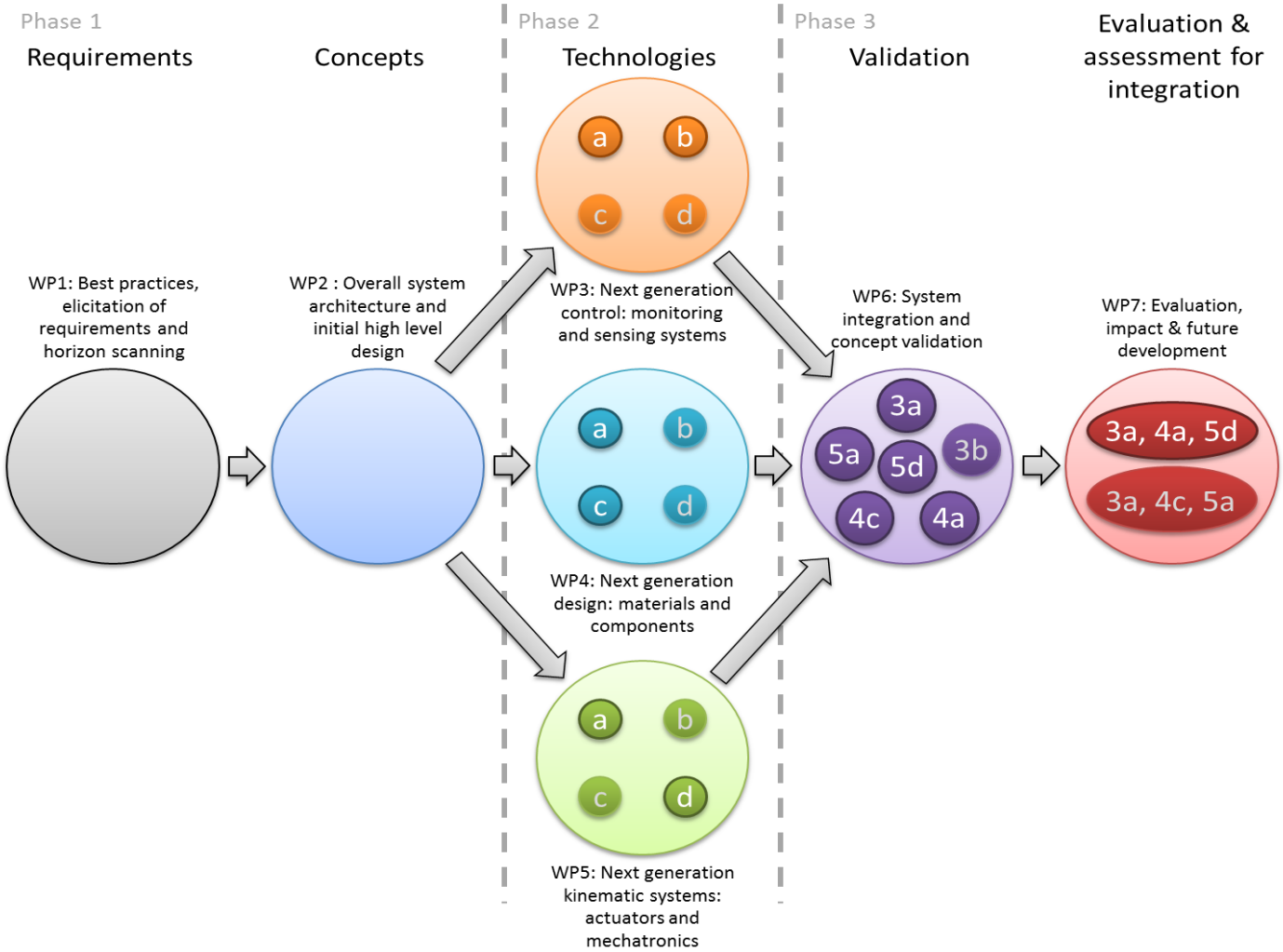








Overall Methodology



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Conclusions

- S-CODE has already identified a significant number of key innovations, and is working on others
- The key to the project is to be able to bring these together within a modular architecture so that innovations can be used either with existing technology, or together to create a totally new concept for switching
- Such an approach should allow innovations to be added to switches during their life – rather than the static view of switches that we have today
- The project ends at TRL 4 in October 2019 – there is then funding to within S-CODE to take forward this (and/or other concepts) to TRL 6.

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