UKRRIN

UK RAIL RESEARCH AND INNOVATION NETWORK

Centre of Excellence in Digital Systems

Delivering a step change in rail transport through digital technology

Part of the UK Rail Research and Innovation Network

UNIVERSITY OF BIRMINGHAM

Lancaster University

Introduction to the Centre

The Centre of Excellence in Digital Systems (CEDS) marries the expertise of two leading UK universities, the University of Birmingham Centre and UKRRIN Network lead and Lancaster University.

Together they unite existing academic and industry capabilities, innovating and supporting transformational change in rail technology across the globe. The CEDS builds on the expertise of the Birmingham Centre for Railway Research and Education (BCRRE), Lancaster University and the UK's industrial base to deliver a step change in rail systems capability, securing a world-leading position in the sector and delivering jobs, growth and inward investment nationally and internationally.

Our Expertise

The CEDS seeks to translate findings into tangible improvements and impacts on railways. Using an integrated system approach, we seek to provide solutions to the railway's grand challenges at component level and sub-system level. BCRRE has an international reputation for developing advanced railway traffic management systems to make better use of existing rolling stock and infrastructure, and to manage disruptions. Our work in this area is helping to define the next generation of railway traffic management and control systems.

CEDS member Lancaster University brings world-leading expertise in the fields of networking, Internet of Things (IoT), data science and cyber security. It is the only NCSC-accredited centre of excellence in cyber security research in the North West of England and much of this activity looks at areas of national critical infrastructure with a human centric approach. Through its interdisciplinary work the team has led and collaborated on research related to the rail sector resulting in applied activities around maintenance, drainage, treefall and platform passenger behaviours.

Railway simulator development

Macroscopic and microscopic railway simulator development for railway research, including a comprehensive microscopic simulator that analyses and evaluates different scales of railway networks with different signalling systems, rolling stock, operational rules and timetables. It has capabilities to integrate with other tools.

Key research for railway traffic management

Advanced algorithm development for railway traffic management; research on application of Driver Advisory Systems; simulation, testing and evaluation for railway traffic management systems; and research on standards of next generation railway traffic management.

Cybersecurity & Internet of Things (IoT)

CEDS members have been exploring security and internet of things technologies for over a decade. The research has moved from a focus on the physical technologies to the application areas where we explore privacy, trust and security around real world deployments. This ranges from the personalisation of information displays in public spaces, to the use IoT to develop efficient maintenance schedules and to monitor behaviours on the platform and in station complexes.

The Remit of the Centre

The Centre focuses on all aspects of digital railway innovation, providing a system-wide approach to transforming research, development and innovation. Technical transformations have a part to play in the delivery of a more cost-effective, customer and carbon-friendly railway that delivers more capacity safely. The development of the CEDS in these areas allows the rail industry to 'get there sooner', thus improving the industry's bottom line and reputation, as well as supporting the UK's export agenda.

Centre locations

- University of Birmingham (Lead)
- Lancaster University

Expertise and Facilities:

Future Railway Operations and Control

- Simulator development
- Traffic management
- System optimisation
- Simulation and testing for integration
- Hardware and humans in-the-loop
- Next generation(s) of control systems and railway digitisation

Data Integration and Cyber Security

- Controlled access to national and international data
- Data modelling and architecture
- Integration of operations and customer-facing systems
- Data-driven railway
- Security and analysis of cyber threats

Smart Monitoring and Autonomous Systems

- Next generations of smart condition monitoring
- Interconnected sensing systems
- Innovations in sensors and sensing
- Intelligent, robotic and autonomous systems
- Innovative self-learning systems
- Real-time scheduling systems
- Machine learning

Introducing Innovation

- Road-mapping of benefit realisation
- Alignment of stakeholders for rapid technology adoption
- Identification of benefits and structuring stakeholder incentives
- System integration testing to speed up approval

Railway Control and Operations Simulation

University of Birmingham

BCRRE has an international reputation for developing advanced railway traffic management systems to make better use of existing rolling stock and infrastructure, and to manage disruptions. Its work in this area is helping to define the next generation of railway traffic management and control systems; the CEDS enhances this capability and accelerates its deployment.

Our capabilities include:

- Railway simulator development: macroscopic and microscopic railway simulator development for railway research, including a comprehensive microscopic simulator that analyses and evaluates different scales of railway networks with different signalling systems, rolling stock, operational rules and timetables. It has capabilities to integrate with other tools;
- Key research for railway traffic management: advanced algorithm development for railway traffic management; research on application of Driver Advisory Systems; simulation, testing and evaluation for railway traffic management systems; and research on standards of next generation railway traffic management;
- Railway system optimisation: energy saving, and railway wireless data communication system modelling and optimisation;
- Simulation and testing lab for railway systems: railway system design validation and verification, and hardware-in-the loop testing.

Condition Monitoring and Sensing

University of Birmingham

BCRRE's condition monitoring work focuses on developing and configuring instrumentation and processing systems that can be used to measure, track and predict the health of various railway subsystems. Such systems improve the operational reliability of the railway, or support business cases for variations in existing maintenance procedures. The group operates over a number of Technology Readiness Levels, from producing systems to support fundamental understanding of a railway subsystem, up to working with companies to develop research into commercial products or applications. The group has worked with major organisations within train operating companies and infrastructure. It has received prestigious awards for engineering innovation at a national level for work using in-service instrumentation to target maintenance on a third rail network. Algorithms developed at Birmingham are also used within Network Rail's Intelligent Infrastructure programme, which continuously monitors the health of over 5,000 sets of points.

Data Integration and Cybersecurity

University of Birmingham

BCRRE investigates fundamental questions about the use of electronic information in the transport domain, from the collection and structured storage of raw data, though efficient processing and algorithms, to the delivery of the appropriate information to staff in a timely manner. Current projects include work on large database design; open data; data exchange and modelling; cyber security; and asset management.

Case Study

Enhanced Points Condition Monitoring (ePCM)

The University of Birmingham has developed a system for Network Rail that uses data from their intelligent infrastructure system which successfully performs fault detection, diagnosis and assesses time to failure. The system is an improvement on the existing point's thresholding system because it can identify more faults at an earlier stage as well as successfully diagnosing the cause. ePCM uses a combination of behind the scenes machine learning and simple rules created by experts to determine the health of the switch in a way that makes sense to maintenance experts.

We are implementing a pilot in 3 routes prior to a national rollout. The feedback gained from the pilot will be used to improve the University of Birmingham's algorithms. This pilot will allow Network Rail to understand the business change impact and define the added value over and above the current 30% of failures detected.

Benefits to Industry

- ✔ Uses existing electrical current sensors
- ✔ Compensates for weather variations
- ✔ Works on all point machines used on Network Rail's infrastructure

Next Steps

- Testing in 3 routes (approximately 300 point machines)
- To develop a professional user interface that is mobile friendly
- National rollout

Security Lancaster

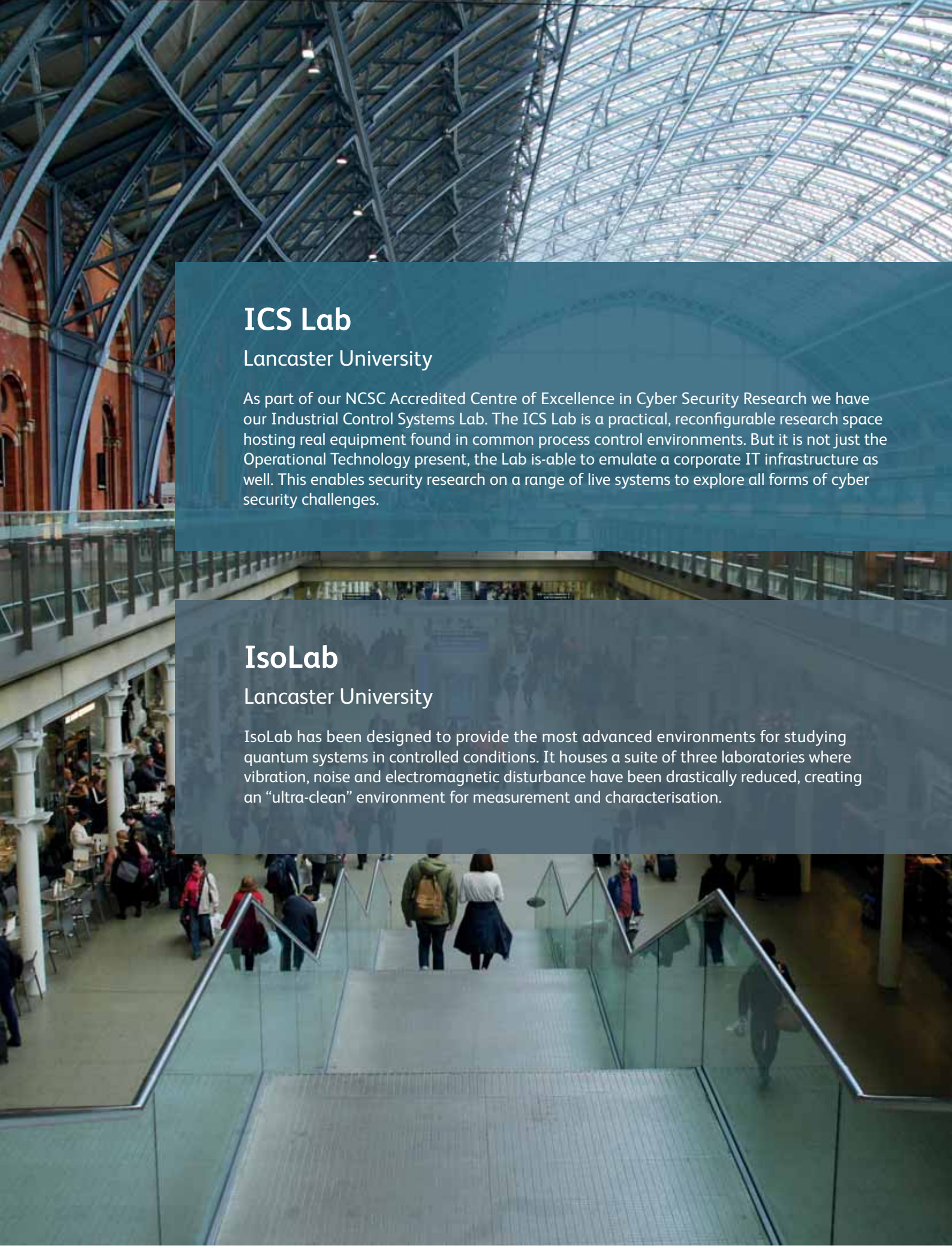
Security Lancaster is one of the largest interdisciplinary security research centres in the UK with a focus on socio-technical systems research allowing it to take a broader view of where the cyber security challenges are and where the solutions may be found. We live in a world in which our ability to capture personal user data far exceeds our understanding of how to manage issues of trust, privacy and consent with potentially far-reaching consequences for both individuals and society.

It is home to the Cyber Security Research Centre, one of the first Academic Centres of Excellence in Cyber Security Research (ACEs-CSR), a national hub for maximising behavioural and social science research into understanding, countering and mitigating security threats.

Cyber Security Research Centre (ACEs-CSR)

The research of the CSRC is focused around four themes: Security of Large-Scale Networks, Security of Cyber Physical Systems and Infrastructures, New forms of Privacy and Identity, and Cyber Security Behaviours. Recognised by the Engineering and Physical Sciences Research Council (EPSRC) and the National Cyber Security Centre (NCSC), along with CREST (Centre for Research and Evidence on Security Threats), it is a well-established multidisciplinary community, it naturally approaches cyber security problems in a disruptive and innovative way. It is a rich, vibrant community of multidisciplinary researchers passionate about driving the development of solutions to the challenges of modern digital life. The unique blend of inter-disciplinary, systems-centred and resilience-focused research on cyber security has led to a range of innovative research programmes – establishing Lancaster as a leading international centre in cyber security research.

Both Security Lancaster and the Cyber Security Research Centre follow the ethos ‘build what we study, and study what we build’. Building on the three foundational elements of – Multidisciplinary Approach, Socio-Technical Systems Research & Real-World Applicability – that enables it to undertake disruptive, innovative research with internationally recognised, socio-economic impact.



ICS Lab

Lancaster University

As part of our NCSC Accredited Centre of Excellence in Cyber Security Research we have our Industrial Control Systems Lab. The ICS Lab is a practical, reconfigurable research space hosting real equipment found in common process control environments. But it is not just the Operational Technology present, the Lab is-able to emulate a corporate IT infrastructure as well. This enables security research on a range of live systems to explore all forms of cyber security challenges.

IsoLab

Lancaster University

IsoLab has been designed to provide the most advanced environments for studying quantum systems in controlled conditions. It houses a suite of three laboratories where vibration, noise and electromagnetic disturbance have been drastically reduced, creating an “ultra-clean” environment for measurement and characterisation.

The Cyber Threat Laboratory

Lancaster University

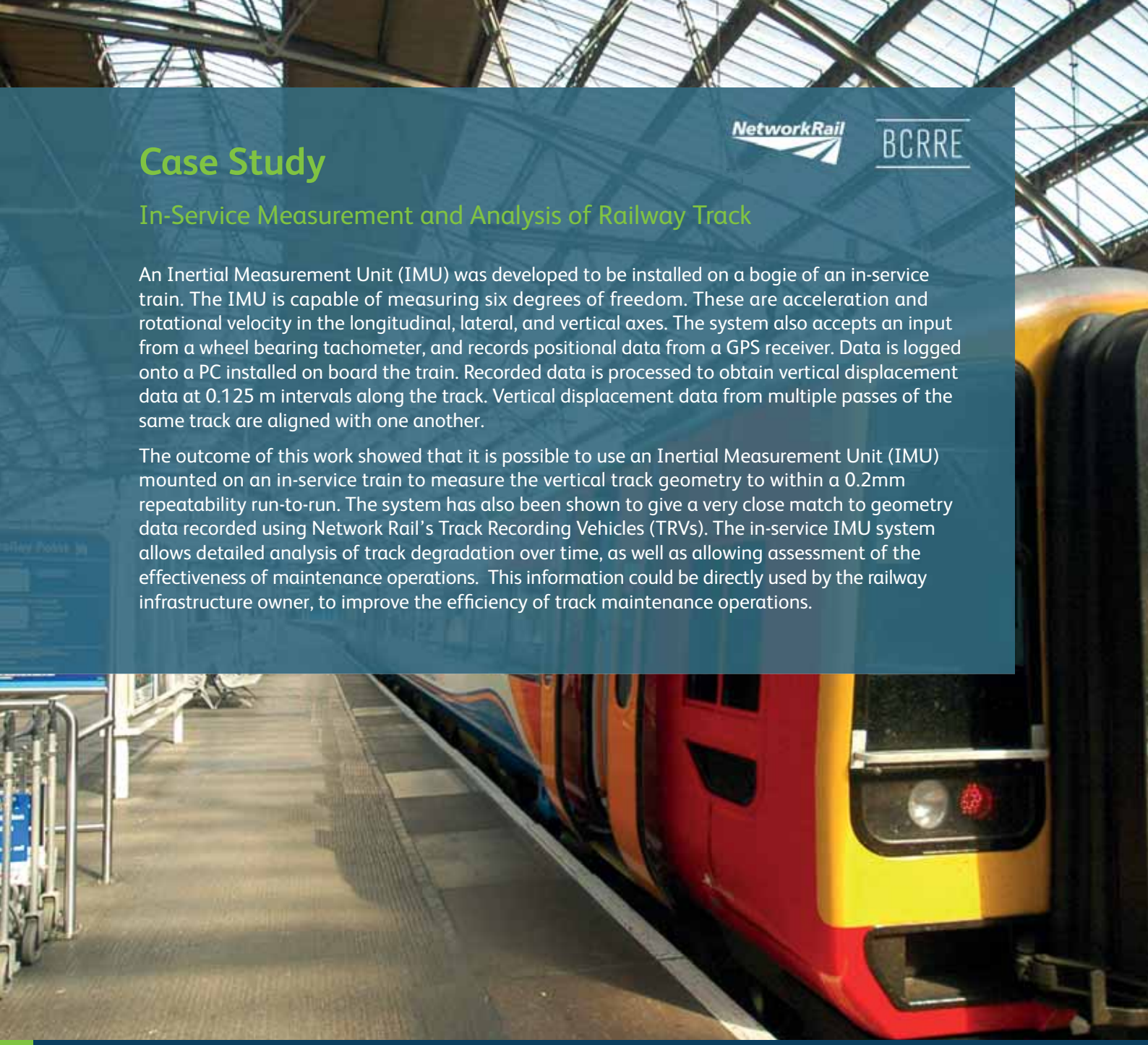
Hosted at Lancaster University the Cyber Threat Laboratory is designed to provide a collaborative platform that allows analysis of threats and behaviour to take place, in a safe and controlled environment. The laboratory provides centralised infrastructure enabling multiple projects and experiments operating simultaneously inside the lab to benefit from mature industry standard tools. Comparable to any research with unknown volatile outcomes, experiments into cyber threats and malware also needs to be handled in a controlled environment with appropriate safeguards and equipment.

Lancaster Intelligent, Robotic and Autonomous systems (LIRA)

The LIRA Research Centre was set up in early 2018 with the aim to bring together the diverse research excellence and expertise in the areas of Intelligent, Robotic and Autonomous Systems (IRAS). Its core is formed by 30 academics from a range of departments all interested similar application domains, including rail. Exploring the impacts of privacy, trust and security issues regarding the use of the IoT to personalise public spaces such as train stations.

Benefits of Collaborating

- Accelerating the development of products, processes and systems through the TRL scale in a 'safe' virtual environment.
- De-risking investment in, and development of, new complex systems delivering verified and better performing outcomes.
- Quickly and confidently testing and verifying business cases.
- Working closely with client and other suppliers on new products and systems in a collaborative workspace.
- Leveraging knowledge and experience from the best research from around the world. Through co-locating a critical mass of research and industry partners with access to a unique set of advanced technical facilities, insight will be gained into the next generation of technologies and the 'innovation landscape' for exploiting these digital technologies in rail.
- Developing new skills and undertaking training on the exploitation of digital rail systems.



Case Study

In-Service Measurement and Analysis of Railway Track

An Inertial Measurement Unit (IMU) was developed to be installed on a bogie of an in-service train. The IMU is capable of measuring six degrees of freedom. These are acceleration and rotational velocity in the longitudinal, lateral, and vertical axes. The system also accepts an input from a wheel bearing tachometer, and records positional data from a GPS receiver. Data is logged onto a PC installed on board the train. Recorded data is processed to obtain vertical displacement data at 0.125 m intervals along the track. Vertical displacement data from multiple passes of the same track are aligned with one another.

The outcome of this work showed that it is possible to use an Inertial Measurement Unit (IMU) mounted on an in-service train to measure the vertical track geometry to within a 0.2mm repeatability run-to-run. The system has also been shown to give a very close match to geometry data recorded using Network Rail's Track Recording Vehicles (TRVs). The in-service IMU system allows detailed analysis of track degradation over time, as well as allowing assessment of the effectiveness of maintenance operations. This information could be directly used by the railway infrastructure owner, to improve the efficiency of track maintenance operations.

Benefits to Industry

- ✔ A low cost system that does not require specially scheduled services
- ✔ High-frequency (e.g. daily) data recordings allow better understanding of the development of faults
- ✔ Works on all point machines used on Network Rail's infrastructure

Next Steps

- Development of a system to automatically identify developing faults, and estimate time to failure.

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