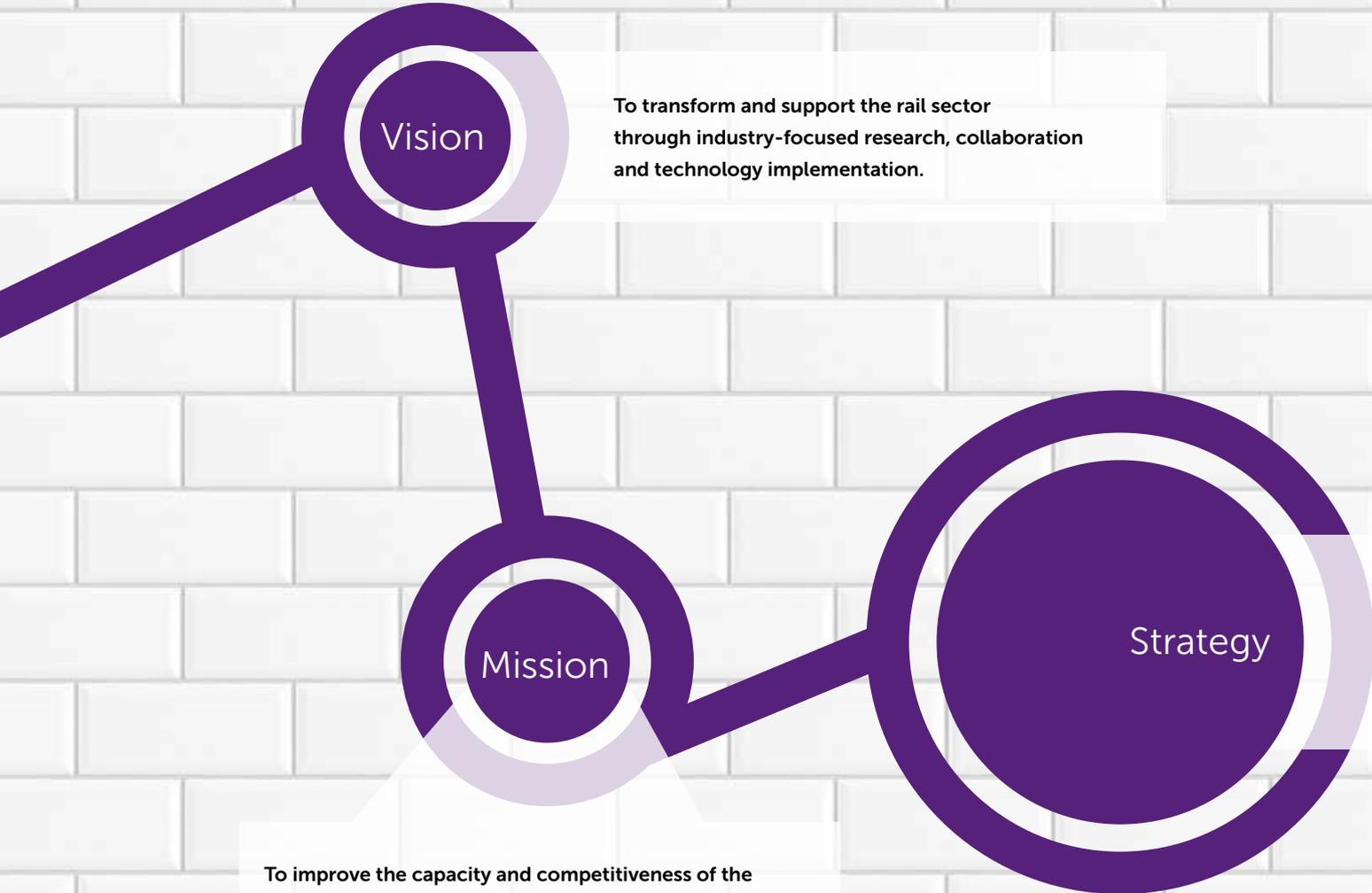




Annual Report 2018–19
Rail Manufacturing CRC





Vision

To transform and support the rail sector through industry-focused research, collaboration and technology implementation.

Mission

To improve the capacity and competitiveness of the Australian rail manufacturing industry and to support its continued integration into global supply chains through the use of new technologies and innovation.

Strategy



Australian Government
**Department of Industry,
Innovation and Science**

Business
Cooperative Research
Centres Program

To promote innovation and create impact in the rail manufacturing industry through cutting-edge research and the commercialisation and implementation of new technologies.

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Message from the Chair and MD

This is the Rail Manufacturing CRC's fifth and penultimate annual report.

Over the course of the last five years, the Rail Manufacturing CRC has continued to expand its programs to deliver excellence in research, technology and training for Australia's rail industry.

Renewed optimism in rail R&D

With our Centre entering its last year of operation and a scheduled wind-up date of 30 June 2020, it is encouraging to see a resurgence of interest in collaborative research and development in Australian rail.

A renewed focus by the Federal and State Governments to build an efficient, nationwide rail system as the fundamental element to transport passengers, goods and services for the next century has re-energised the industry.

With a pipeline full of projects, the rail industry is experiencing unprecedented demand and opportunity – Government investment in current and future rail infrastructure and rolling stock is tipped to exceed \$150 billion over the next thirty years. The coming decades will truly be a golden age for rail in Australia.

In the Centre's early years, the downturn in the heavy rail manufacturing and supply sectors severely impacted the ability of our Industry and Research Participants to pursue heavy rail related projects. In comparison, the recent upturn in the resources sector and the continuing growth in passenger rail infrastructure and rolling stock highlights market optimism.

With this substantial investment comes immense opportunities for Australia to build its blue and white collar workforce, to use future investment to support the creation and adoption of new domestic rail technologies, to build new supply chains based on emerging technologies, to fund domestic innovation initiatives, and most importantly, for rail to attract and retain a new and emerging workforce of highly skilled engineers and science professionals that will lead the industry into the future.

Projects going strong

For the past 12 months, the Rail Manufacturing CRC has been actively engaged in workshopping, evaluating and implementing a variety of new projects by both existing partners and new Participants. In 2018–19 alone, our team has initiated seven new projects with a total cash funding of \$8.7 million, leading progressive research in battery back-up systems, predictive maintenance solutions, responsive passenger information technologies and defining future rail workforce needs.

The increase in project activity also mandated a required amendment to the Commonwealth Agreement, which occurred in January 2019. This included general updates to milestones and budget, plus the incorporation of terms and conditions to reflect new Commonwealth requirements relating to CRC funding agreements. As always, our interactions with the Department of Industry, Innovation and Science team have been constructive and positive, and we continue to acknowledge the support they provide and the key role they play with our Centre and Participants.

Furthermore, the successful outcomes of our projects could not have been achieved without the strong support of our Industry and Research Participants, working collaboratively to deliver shared goals. This annual report outlines some of these achievements in detail, but it should be noted that most of our collaborations have been exemplary and have produced world-class outcomes with a strong prospect of enduring future partnerships.

Indeed, in the past year, relationships between several of our Participant organisations are now considered to be at their most productive since our Centre began, including:

- » **Downer and UTS** developing the Dwell Track™ responsive passenger information technology which can monitor platform and causeway congestion in rail environments, with a Sydney Trains trial commencing in August 2019
- » **CRRC and CSIRO** undertaking a range of projects primarily focussed on energy storage activities and metal processing
- » **Bombardier and University of Queensland** delivering projects in monitoring and modelling to better predict bearing wear and maintenance cycles
- » **Airlinx and RMIT University** developing computer aided design systems to understand airflow within rail carriages and designing more effective means to deliver and recirculate air.

Special recognition also goes to Knorr-Bremse and Sydney Trains for both continuing to commit to a wide range of projects throughout the years. Both businesses have identified projects that aim to deliver potentially transformative outcomes for their future operations.



Dr Stuart Thomson



Paul Johnson MBE

The buoyant rail sector is also reflected in terms of our PhD student commitments. It's extremely encouraging to see the very strong cohort of students conducting highly challenging research for the rail industry, with a number of students beginning to submit their theses and planning to embark on a career in rail upon completion of their PhD studies.

Rail R&D moving forward

Despite the best efforts of the Centre and its Industry Participants to realise the initial commitments made in 2014, some organisations are unlikely to meet their obligations to the Centre, with a shortfall in total project activity expected.

These shortfalls are due to an ongoing global rail industry consolidation witnessed by numerous recent mergers and acquisitions, management restructures, financial challenges, and subsequent changes to innovation strategies and priorities, all of which have contributed to the volatility within the sector for a number of our Industry Participants over the last five years.

Despite this, the Rail Manufacturing CRC's short tenure is best characterised as contributing not only to delivering new technologies and knowledge to the sector, but also building an awareness about the importance of R&D in a local manufacturing environment.

By fostering strong working relationships between Industry Participants and publicly-funded research agencies since 2014, it is hoped that these partnerships, formed by the Rail Manufacturing CRC, will serve the sector for many years to come.

The Centre has also contributed to raising awareness of the impending shortfall in highly skilled, research-trained, next generation rail workers, and likewise our team is buoyed to see a growing program of activity developed by industry to attract future graduates and postgraduates to the sector.

Project progression during transition stages

With less than 12 months to go until the Rail Manufacturing CRC's impending wind-up, there are some project proposals that cannot be undertaken predominately due to a lack of time. In these instances, every effort is being made to find alternative funding mechanisms to support these projects, whether with another Cooperative Research Centre, as a CRC-Project, with a Growth Centre or via other avenues.

The Rail Manufacturing CRC will remain operational until the end of September 2020 for final reporting and financial tracking. Our team is committed to managing this transition in a timely, transparent and seamless manner – with further details outlined in this report's wind-up plan overview.

The ongoing realisation of additional challenging and relevant rail industry projects, combined with the success of the Centre's many existing projects, may suggest the ongoing need for a rail-related research centre post the Rail Manufacturing CRC's closure. At a minimum, it clearly highlights the positive contribution that the Rail Manufacturing CRC has made to the future of Australian manufacturing and the broader rail sector.

Thanks for your support

Our thanks and recognition go to our Board and Management teams for their commitment and drive this year.

Thank you to our Industry and Research Participants, many of whom who have been actively engaged since the Centre first commenced in 2014. It's been a pleasure working with you to identify innovation projects that provide key improvements to help grow the Australian rail sector.

We appreciate your continued support during our upcoming final year, and as always, thank you for working with us to build an Australian rail industry committed to innovation and R&D.

Paul Johnson MBE
Chair – Rail Manufacturing CRC

Dr Stuart Thomson
CEO – Rail Manufacturing CRC

About the Rail Manufacturing CRC

The Rail Manufacturing Cooperative Research Centre (CRC) was established in 2014 to build a collaborative research and development program between Australia's rail manufacturing industry and world-leading Australian education institutions.

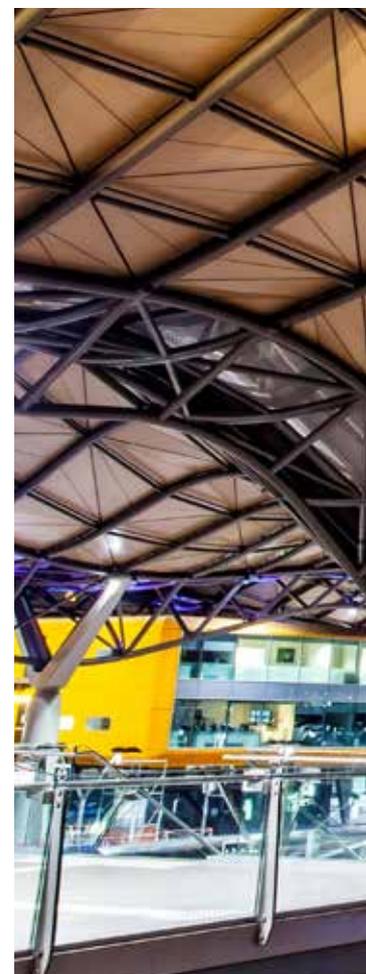
The Centre manages partnerships between key stakeholders, including rail manufacturing multinationals, Australian small-to-medium enterprises, research and development providers, industry peak bodies, and Australian State and Federal Governments.

Funded by participating rail organisations and the Business Cooperative Research Centres Program of the Federal Government's Department of Industry, Innovation and Science, the Rail Manufacturing CRC is now five years into its six-year lifespan. The Centre is scheduled to cease operations on 30 June 2020.



Australian Government
**Department of Industry,
Innovation and Science**

Business
Cooperative Research
Centres Program



Research underway in:

01

Power and Propulsion

- » Battery development and manufacture
- » Supercapacitor technologies
- » Rail-wheel-interface
- » Composite braking
- » Energy harvesting

02

Materials and Manufacturing

- » Component durability testing
- » Maintenance optimisation
- » Composite materials design
- » Automated assembly
- » Advanced welding and cladding

03

Design, Modelling and Simulation

- » Passenger information systems and dwell time management
- » Cabin airflow modelling
- » Data transfer and analytics
- » Virtual and augmented reality rail training

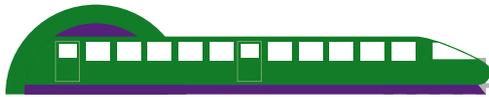


Southern Cross Station, Melbourne

In 2018–19...

30

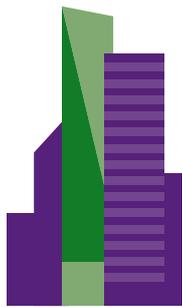
Publications
achieved



48 F
Student
commenc



25 Industry
projects underway
this year



29
partici
organisa



PhD
theses
submitted



2

PhD theses
submitted



Operating
operations

Keeping the Centre *on track*



Executive summary



Dr Stuart Thomson accepts the Excellence in CRC award in May 2019

Achievements

Research and collaboration

In its fifth year of operation, the Rail Manufacturing CRC's research program has witnessed an array of outputs that are beginning to be implemented by the rail sector.

A key event in this year's calendar occurred in May 2019, when the Rail Manufacturing CRC, Downer and the University of Technology Sydney received an Excellence in Innovation award from the Cooperative Research Centre Association for Project R3.1.2 - **Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system** (Downer / University of Technology Sydney). The outputs from this project are currently being commercialised as a passenger dwell-time monitoring technology called Dwell Track™. The final phase of this project was pre-commercial trials which are being conducted with the assistance of Sydney Trains.

Seven new project agreements were executed in 2018–19:

- » Project R1.3.5 - **Lighting and control battery backup** (Downer / CSIRO):
The delivery of battery prototypes for lighting and control system backup.
- » Project R1.3.6 - **Battery pack durability** (Knorr-Bremse / CSIRO):
Investigating improved battery durability to provide increased reliability and cost savings through more efficient battery replacement cycles.
- » Project R2.1.3 - **Laser repair of railway cast components** (CRRC / CSIRO):
Developing a smart and reliable technology to repair steel casting defects without having thermal damage in surrounding regions.
- » Project R3.1.3 - **Predictive maintenance models for Sydney Trains** (Sydney Trains / University of Technology Sydney):
The identification and definition of Sydney Trains case studies and the development of a proof-of-concept predictive maintenance demonstrator.
- » Project R3.1.4 - **Intelligent data fusion and analytics framework** (Downer / Deakin University):
The design and development of a data fusion and analytics framework, to be assessed for predictive train maintenance services for Downer's TrainDNA project.



Project representatives from the University of Technology Sydney, Downer and the Rail Manufacturing CRC at the CRC awards dinner

- » Project R3.2.2 - **Development of a responsive passenger information system for the Sydney Trains network (stage 2)** (Sydney Trains / University of Technology Sydney):
Delivery of a passenger information system technology demonstrator.
- » Project R3.3.3 - **Reimagining the workforce: building smart, sustainable and safe public transport** (Department of Transport / Victoria University):
Undertaking assessments to better understand future resourcing requirements of the rail manufacturing and rolling stock sectors.

Commercialisation and utilisation

The Rail Manufacturing CRC's model for commercialisation and utilisation was developed in close consultation with its Industry and Research Participants, with an overarching principle to support and facilitate industry-led research outcomes.

As of June 2019, four Rail Manufacturing CRC projects were completed during the year:

- » Project R1.3.3 - **High energy supercapacitor development** (CRRC / CSIRO):
The production of a supercapacitor device with good cycle life and power that maintains sufficient energy density. Further work may be required to improve the electronic conductivity of the device.

- » Project R2.3.2 - **Axle bearing maintenance optimisation** (Bombardier / University of Queensland):
Investigating the wear and degradation of axle bearings used in a suburban fleet for passenger transport. This project created a model and tool to optimise bearing wear by selecting lubricant and maintenance parameters, with a goal to extend the life of bearings operating well below their fatigue threshold.
- » Project R3.3.2 - **Development of a smart rail route map** (Australasian Railway Association / Deakin University):
This project developed a 30-year framework to define rail industry direction, development initiatives and research programs required for the successful integration and support of next-generation digital and telecommunications technologies.
- » Project R3.5.1 - **Battery HVAC feasibility study** (Knorr-Bremse / CSIRO):
This study will enable the participating organisations to undertake future activities relating to battery use in heating, ventilation and air-conditioning systems with much deeper insights into the background technology involved.

Developed utilisation plans have resulted in all utilisation milestones being achieved during the reporting period – see page 36 for more information.

Executive summary, continued.

Education and training

The Rail Manufacturing CRC has continued its commitment to delivering a strong education program and supporting its students to consider future employment in Australia's rail industry after graduation.

In the past 12 months, the number of PhD students supported by the Centre has risen to a high of 48 spread across industry projects, PhD scholarships and industry internships.

With this ever-increasing number of students supported by the Centre, the Rail Manufacturing CRC has continued to deliver ongoing support and guidance to its student cohort. In March 2019, the Centre hosted its second annual PhD Students' Forum in Melbourne. In addition, the students have further been supported through:

- » Career readiness training sessions throughout 2019
- » Participation in and presentation at key rail and industry events
- » Ongoing training, support and guidance

With most students now well progressed into their PhD research, a number of students have been recognised this year. This includes Monash University PhD student Wenhua Jiang, who was awarded a Graduate Research International Travel Award, and University of Wollongong PhD student Chuhao Liu, who was selected as one of six finalists for the 2019 TEDxSydney Kick Start competition in May 2019.

There are seven active education-related milestones, three of which have been achieved and four are in progress – see page 29 for more information.





Newcastle's light rail network commenced operation in February 2019



Executive summary, continued.

Risks and impediments

The Rail Manufacturing CRC continues to focus on its Commonwealth Milestones to deliver projects that create impact for the organisations involved, as well as for the broader rail manufacturing industry.

In the past 12 months, the Centre's Board and Management team have reviewed and developed the Centre's project portfolio by continuing its engagement with Participant organisations and seeking to identify new projects with current and new Participants.

The risks associated with any research and development entity working in the manufacturing sector are typically dependent on the global economic environment, domestic and international demand for manufactured products, the nature of competitive global supply, the general level of confidence within the sector, and the capacity of domestic manufacturers to invest in research, innovation, capital equipment, and human resources.

The key risks to the Rail Manufacturing CRC primarily relate to the slow uptake of projects by industry in the initial years of the Centre relating to:

- » the downturn in commodity prices, thereby affecting demand for heavy haul equipment and subsequent heavy haul R&D work
- » the increased demand in passenger rail manufactured products which dramatically changed the focus of the domestic industry players
- » restructures, financial hardship, mergers and acquisitions that occurred within most of the Centre's Industry Participant organisations in the early years, resulting in delays or modified R&D strategies.



Freight rail deliveries underway

The Rail Manufacturing CRC has not been immune to such external factors, but has managed to overcome these challenges due to its capacity for flexibility and its close working relationship with its Participants. This has resulted in:

- » an increased number of Participants – with the Department of Transport (Victoria) and Victoria University joining the Centre this year
- » the commencement of seven new projects
- » engagement with industry peak bodies (such as the Australasian Railway Association and the Rail Industry Safety and Standards Board) and Government-led initiatives (such as the Innotrans 2018 delegation) to inform the rail sector about the Centre's activities.

By continuing to focus on these strategies, the Rail Manufacturing CRC has been able to improve its performance against its Commonwealth Milestones, while also building stronger long-term relationships with its Research and Industry Participants.

Impacts

New projects commencing

The Rail Manufacturing CRC has been active in developing new projects in 2018–19, with seven new project agreements executed:

Project R1.3.5 - **Lighting and control battery backup** (Downer / CSIRO):

This project will deliver battery prototypes for backup of lighting and control systems. Cells will be assessed and tested for required properties including lifetime, energy density and safety, and ultimately be integrated into the train's operating system.

Project R1.3.6 - **Battery pack durability** (Knorr-Bremse / CSIRO):

The substantiation of improved battery durability to provide increased reliability and cost savings through more efficient battery replacement cycles.

Project R1.5.1 - **Aluminium matrix composite brake discs** (CRRRC / CSIRO):

CSIRO has established an in-house lab-scale wear testing facility to test the full-sized aluminium matrix composite brake discs being produced onsite. If the new brake discs pass laboratory test requirements, CRRRC will conduct locomotive trials using them.

Project R2.1.3 - **Laser repair of railway cast components** (CRRRC / CSIRO):

This project will develop a smart and reliable technology to repair steel casting defects without having thermal damage in the surrounding regions. It is a robotic process which will reduce casting parts rejection rates by rapid laser repair of defects.

Project R3.1.3 - **Predictive maintenance models for Sydney Trains** (Sydney Trains / University of Technology Sydney):

Involving the identification and definition of Sydney Trains case studies and the development of a proof-of-concept predictive maintenance demonstrator.

Project R3.1.4 - **Intelligent data fusion and analytics framework** (Downer / Deakin University):

The design and development of a generic multi-modal data fusion and analytics framework using machine learning, statistical and other complementary models. The efficacy of the framework will be assessed for predictive train maintenance services, as part of Downer's TrainDNA project.

Project R3.2.2 - **Development of a responsive passenger information system for the Sydney Trains network (stage 2)** (Sydney Trains / University of Technology Sydney):

This work comprises the delivery of separate engineering and research components. The engineering component is focused on delivering a technology demonstration, while the research components continue from the work done in the first stage of the project.

Project R3.3.3 - **Reimagining the workforce: building smart, sustainable and safe public transport** (Department of Transport (Victoria) / Victoria University):

Activities focused on undertaking assessments to gain insights in future public transport sector resourcing requirements for the rail manufacturing and rolling stock sectors.



Members of the axle bearing project team at the University of Queensland

Project extensions

Extensions were made to two projects in 2018–19 to increase the scope of works:

Project R3.1.2 - **Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system** (Downer / University of Technology Sydney):

This project was varied to enable a trial of the Dwell Track™ technology at Wynyard station by Sydney Trains, which commenced in August 2019.

Project R3.3.2 - **Development of a smart rail route map** (Australasian Railway Association / Deakin University):

This work was extended to broaden the project scope to include the development of a framework to support the Smart Rail map's implementation.

Project completions

Four projects were completed during the last 12 months, including:

Project R1.3.3 - **High energy supercapacitor development** (CRRC / CSIRO):

This project involved the development and testing of prototype energy storage devices. These new supercapacitor devices have higher energy density than traditional supercapacitors and also

have a better cycle life than most lithium batteries. Towards the end of the project, CRRC Project Leader Ruijie Qin travelled to Australia to assist the CSIRO team with technology transfer and commercial input.

Project R2.3.2 - **Axle bearing maintenance optimisation** (Bombardier / University of Queensland):

In this project, a model and tool were created to optimise bearing wear by selecting lubricant and maintenance parameters to potentially extend the life of bearings operating well below their fatigue threshold.

Project R3.3.2 - **Development of a smart rail route map** (Australasian Railway Association / Deakin University):

The Smart Rail Route Map provides a framework for improving the industry's ability to adopt and keep pace with telecommunication and information-based technologies to improve standardisation, integration and harmonisation over the next 30 years.

Project R3.5.1 - **Battery HVAC feasibility study** (Knorr-Bremse / CSIRO):

The battery HVAC feasibility study will enable the participating organisations to undertake future activities with much deeper insights into the background technology involved.

Performance against activities

01

Power and Propulsion

Energy and cost efficiency, and improved competitive performance in advanced rail manufacturing through research, development and commercialisation in:

- » Energy Regeneration and Storage
- » Advanced Braking Systems
- » Electronic Motors and Systems

02

Materials and Manufacturing

Competitive cost, durability and performance in advanced rail manufacturing through research, development and commercialisation in:

- » High Performance Materials For Heavy Haul
- » Advanced Manufacturing
- » Advanced Lightweight Materials
- » Low Cost Manufacturing Systems

03

Design, Modelling and Simulation

Safety and efficiency in advanced rail manufacturing to enhance industry competitiveness through research, development and commercialisation in:

- » Advanced Design and Simulation
- » Automated Health Monitoring
- » Advanced Data Analysis and Information Systems
- » Advanced Operations Management Systems
- » Energy Use Management Tools



01
Power and Propulsion

Development of supercapacitor technologies at CSIRO

Program 1 – Power and Propulsion

The relevance of the Centre's focus on battery and supercapacitor systems was further supported at InnoTrans 2018 in Berlin, where leading rail businesses are starting to deliver different power solutions to the rail industry.

The benefits of hybrid systems for diesel locomotives include reduced emissions at stations, regenerative braking, and the ability to operate under diesel or electric power when needed. For electrified lines, a hybrid system offers the ability to operate in non-electrified sections such as line extensions or areas where overhead lines are not possible due to height limitations or environmental sensitivity.

Related to Rail Manufacturing CRC projects, this electrification challenge is extended to entirely catenary-free light rail systems where the overhead lines are replaced by charging stations at tram stop platforms.

During the year, the strong collaboration between China Railway Rolling Stock Corporation (CRRC) and CSIRO has continued through a suite of supercapacitor energy storage system projects, including:

- » Project R1.3.3 - **High energy supercapacitor development** (CRRC / CSIRO)
- » Project R1.3.4 - **Supercapacitor energy management system stage 2** (CRRC / CSIRO)

In particular, Project R1.3.3 - **High energy supercapacitor development** (CRRC / CSIRO) was completed during the reporting period, resulting in the testing of a supercapacitor that maintains good cycle life and power density whilst improving energy density compared with traditional supercapacitors.

As part of the PhD activity undertaken at Queensland University of Technology, lithium iron phosphate (LFP), one of the important commercial battery materials, was investigated to determine electrochemical, electrical and magnetic properties. In this study, the presence of iron phosphate was found to significantly improve the electronic conductivity.

Project R1.3.4 - **Supercapacitor energy management system stage 2** (CRRC / CSIRO) has continued progressing through laboratory tests at CSIRO, and is scheduled for completion following full-sized tests to be conducted at CRRC's facility in China by CSIRO and CRRC technical staff in late 2019.

An additional two new battery-related projects look at the energy battery backup options provided by modern battery chemistries for trains – Project R1.3.5 - **Lighting and control battery backup** (Downer / CSIRO) and Project R1.3.6 - **Battery pack durability** (Knorr-Bremse / CSIRO).

In a similar theme, two battery and supercapacitor material-focused projects between the HEC Group and the University of Technology have also delivered promising laboratory results. In Projects R1.1.1 - **New generation lithium ion batteries with high energy density and long service life for rail industry application** (HEC Group / University of Technology Sydney) and R1.1.2 - **Hybrid supercapacitors with high energy and power densities for rail industry applications** (HEC Group / University of Technology Sydney), improved materials are showing promising increases in energy density while maintaining other required parameters of cycle life and power density.

One final project that addresses the advanced braking research component of Program 1 has also progressed well during the reporting period. Project R1.5.1 - **Aluminium matrix composite brake discs** (CRRC / CSIRO) involves the production of full-sized composite brake discs produced at the CSIRO facility. The composite brake disc seeks to address several operational considerations to achieve better in-service performance, with the CRRC division QSY (Qishuyan Institute Co, Ltd) to undertake ongoing testing of the brake disc in their facilities.

Performance against activities, continued.

Program 2 – Materials and Manufacturing

This program area incorporates a variety of projects primarily relating to maintenance and durability of rail track and rolling stock, which has emerged as a key focus for industry due to Australian build-maintain contracts granted for efficient maintenance and servicing of rail assets.

Two projects in partnership between Bombardier and the University of Queensland could significantly reduce the rail industry's maintenance and overhaul requirements.

For Project R2.3.2 - **Axle bearing maintenance optimisation** (Bombardier / University of Queensland), which completed in the last 12 months, this project developed and tested a new enhanced predictive maintenance system for axle bearings. This work has enabled Bombardier to progress commercial activities in optimising axle bearing maintenance.

The other project due to complete shortly is Project R2.3.4 - **Monitoring and control of false brinelling** (Bombardier / University of Queensland), which investigates the wear that can occur during the transportation of bearings due to vibration and/or load on the bearing.

In Project R2.3.1 - **Accelerated life testing and characterisation of critical components** (Knorr-Bremse / CSIRO), Knorr-Bremse is working with CSIRO to test the performance of air conditioning units in different atmospheric conditions.

In Project 2.1.1 - **Platform gap** (Downer / Monash University), this project is focused on the manufacture and testing of a dynamically-adjustable gap filling device between the train and platform.

Another two projects focus on researching materials to enable rail ballast stability – Project R2.5.1 - **Performance of recycled rubber inclusions for improved stability of railway** (Tyre Stewardship Australia / Australasian Centre for Rail Innovation / University of Wollongong) and Project R2.5.2 - **Application of geogrids for minimising track deformation and degradation under high frequency cyclic and heavy haul loading** (Global Synthetics / Foundation QA / University of Wollongong).

Project R2.5.1 involves researching the use of recycled tyres as an alternate product for use in the rail ballast, while Project R2.5.2 is looking into the use of geogrids to stabilise the ballast foundation. A series of large-scale tests are currently in progress to investigate the behaviour of the rail ballast with and without geogrid reinforcement under cyclic loading conditions.

Project R2.1.2 - **Protection of cast steel coupler from corrosion by cold spray** (CRRG / CSIRO) is investigating the use of cold spray techniques to maintain and prolong coupler lifetime. Cold spray is an efficient and environmentally-friendly method of metal coating that uses a supersonic jet to spray metal particles to bond and form a protective metal layer.

In Program 2, one new project commenced during the year – Project R2.1.3 - **Laser repair of railway cast components** (CRRG / CSIRO). The project team is looking to develop a smart and reliable technology to repair steel casting defects without thermal damage in the surrounding regions. It is a robotic process which will reduce the rejection rate of cast parts by rapid laser repair of defects.

One project was terminated during the Financial Year – Project R2.4.1 - **Advanced steel development for rail and sleepers** (OneSteel / Monash University), due to OneSteel's withdrawal from the project following its parent company, Arrium, being placed in voluntary administration and subsequently sold to new owners.

02

Materials and Manufacturing



Projects underway focused on ballast stability

Program 3 – Design, Modelling and Simulation

The potential benefit of data analytics and predictive maintenance in rail has resulted in significant new activity during the year. Predictive maintenance offers the potential to implement technologies to monitor asset health, optimise maintenance schedules and gain real-time alerts to operational risks.

New projects commencing in the last 12 months include:

- » Project R3.1.3 - **Predictive maintenance models for Sydney Trains** (Sydney Trains / University of Technology Sydney): Identification of case studies and development of a proof-of-concept predictive maintenance demonstrator using an inhouse tool developed by UTS.
- » Project R3.1.4 - **Intelligent data fusion and analytics framework** (Downer / Deakin University): Developing a generic multi-modal data fusion and analytics framework using machine learning, statistical and other complementary models, to be assessed for predictive train maintenance services.
- » Project R3.2.2 - **Development of a responsive passenger information system for the Sydney Trains network (stage 2)** (Sydney Trains / University of Technology Sydney): This project builds upon outcomes from a previous project. Stage 2 will deliver a demonstrable passenger information system at Town Hall station, allowing the collection of insights into customer movements from existing CCTV, Dwell Track™ and Wi-Fi in real-time.
- » Project R3.3.3 - **Reimagining the workforce: building smart, sustainable and safe public transport** (Department of Transport (Victoria) / Victoria University): Undertaking assessments to gain insights into future public transport sector resourcing needs.

Within this research area, Project R3.1.2 - **Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system** (Downer / University of Technology Sydney) was extended to trial the technology with Sydney Trains. Commencing in August 2019, the trial involves the installation of Dwell Track™ to monitor the movement of passengers.

Another project underway is Project R3.4.1 - **Arc welding modelling** (CRRC / CSIRO). CSIRO's arc welding software allows accurate prediction of the heat transfer to the welded metal, expected to greatly reduce the number of tests required in developing weld designs for rolling stock fabrication.

Project R3.6.1 - **Experimental and computational study on the key ventilation issues affecting air quality and thermal comfort in train cabins** (Airlinx / RMIT University) involves the development of a 3D computational fluid dynamics (CFD) model to predict thermal airflow and contaminant dispersion in train cabins.

The completion of Project R3.3.2 - **Development of a smart rail route map** (Australasian Railway Association / Deakin University) provides a framework for improving the rail industry's ability to adopt telecommunication and information-based technologies to improve standardisation, integration and harmonisation over the next 30 years. A Smart Rail Executive Committee has been established to guide the implementation of the Smart Rail Route Map.

Project R3.5.1 - **Battery HVAC feasibility study** (Knorr-Bremse / CSIRO) was also completed during the reporting period, enabling Knorr-Bremse and CSIRO to undertake future activities in heating, ventilation and air-conditioning battery use with much deeper insights into the technology involved.



Performance against activities, continued.

Rail Manufacturing CRC Projects current during reporting period

Number	Project	Participants	
Program 1 – Power and Propulsion			
1	R1.1.1	New generation lithium-ion batteries with high energy and long service life for rail industry applications	HEC Group / University of Technology Sydney
2	R1.1.2	Hybrid supercapacitors with high energy and power densities for rail industry applications	HEC Group / University of Technology Sydney
3	R1.3.3	High energy supercapacitor development	CRRC / CSIRO
4	R1.3.4	Supercapacitor energy management system stage 2	CRRC / CSIRO
5	R1.3.5	Lighting and control battery backup	Downer / CSIRO
6	R1.3.6	Battery pack durability	Knorr-Bremse / CSIRO
7	R1.5.1	Aluminium matrix composite brake discs	CRRC / CSIRO
Program 2 – Materials and Manufacturing			
8	R2.1.1	Platform gap	Downer / Monash University
9	R2.1.2	Protection of cast steel coupler from corrosion by cold spray	CRRC / CSIRO
10	R2.1.3	Laser repair of railway cast components	CRRC / CSIRO
11	R2.3.1	Accelerated life testing and characterisation of critical components	Knorr-Bremse / CSIRO
12	R2.3.2	Axle bearing maintenance optimisation	Bombardier / University of Queensland
13	R2.3.4	Monitoring and control of false brinelling	Bombardier / University of Queensland
14	R2.4.1	Advanced steel development for rail and sleepers	OneSteel / Monash University
15	R2.5.1	Performance of recycled rubber inclusions for improved stability of railways	Tyre Stewardship Australia / Australasian Centre for Rail Innovation / University of Wollongong
16	R2.5.2	Application of geogrids for minimising track deformation and degradation under high frequency cyclic and heavy haul loading	Global Synthetics / Foundation QA / University of Wollongong
Program 3 – Design, Modelling and Simulation			
17	R3.1.2	Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system	Downer / University of Technology Sydney
18	R3.1.3	Predictive maintenance models for Sydney Trains	Sydney Trains / UTS
19	R3.1.4	Intelligent data fusion and analytics framework	Downer / Deakin University
20	R3.2.2	Development of a responsive passenger information system for the Sydney Trains network (stage 2)	Sydney Trains / UTS
21	R3.3.2	Development of a smart rail route map	Australasian Railway Association / Deakin University
22	R3.3.3	Reimagining the workforce: building smart, sustainable and safe public transport	Department of Transport / Victoria University
23	R3.4.1	Arc welding modelling	CRRC / CSIRO
24	R3.5.1	Battery HVAC feasibility study	Knorr-Bremse / CSIRO
25	R3.6.1	Experimental and computational study on the key ventilation issues affecting air quality and thermal comfort in train cabins	Airlinx / RMIT University

Commonwealth Milestone status as at 30 June 2019

Milestone number	Milestone	Due date	Status
Program 1 – Power and Propulsion			
R1.1.2	Design of system hardware and/or software confirmed. IP strategy (patents/know-how/designs/software) defined	30 Jun 2018	Achieved
R1.1.3	Demonstrator built	30 Jun 2019	Achieved
R1.3.4	Evaluation and validation report approved	31 Dec 2018	Achieved
R1.3.5	Scale up and commercialisation report approved. Conduct full scale trials	30 Jun 2019	Achieved
R1.4.3	Demonstrator built	31 Dec 2018	Achieved
R1.4.4	Report approved for evaluation and validation of Demonstrator	30 Jun 2019	Achieved
R1.5.2	Commencement of 4 PhD students	30 Jun 2017	Achieved
R1.5.3	Commencement of 3 PhD students	30 Jun 2018	Achieved
R1.5.4	Completion of 1 PhD students	30 Jun 2019	In Progress
Program 2 – Materials and Manufacturing			
R2.1.6	Test and evaluate component and manufacturing process completed	31 Dec 2018	Achieved
R2.1.7	Final report approved and release IPR for utilisation/commercialisation. Start of Production	30 Jun 2019	Achieved
R2.2.3	Software model to predict performance completed	30 Jun 2019	Achieved
R2.3.4	Validated model for physical and predicted data	31 Dec 2018	Achieved
R2.3.5	Design and develop component and manufacturing process completed	30 Jun 2019	Achieved
R2.4.6	Test and evaluate component and manufacturing process field trials completed	31 Dec 2018	Achieved
R2.4.7	Final report approved and release IPR for utilisation/commercialisation	30 Jun 2019	Achieved
R2.5.4	Completion of 1 PhD students	30 Jun 2018	Achieved
R2.5.5	Completion of 3 PhD students	30 Jun 2019	In Progress
Program 3 – Design, Modelling and Simulation			
R3.1.5	Design and develop component and manufacturing process completed	31 Dec 2018	Achieved
R3.1.6	Test and evaluate component and manufacturing process field trials completed	30 Jun 2019	Achieved
R3.3.2	Provisional patent/s/publications lodged for algorithms for rail applications	30 Dec 2018	Achieved
R3.3.3	Report approved for know-how for algorithms for rail applications	30 Jun 2019	Achieved
R3.3.4	Demonstrator algorithms for rail applications and commercialisation plan completed	30 Jun 2019	Achieved
R3.4.3	Software model to predict performance completed	30 Jun 2018	Achieved
R3.5.3	Software model to predict performance completed	30 Dec 2018	Achieved
R3.5.4	Validated model for physical and predicted data	30 Jun 2019	Achieved
R3.6.6	Computer simulation of train cabin completed	31 Dec 2018	Achieved
R3.7.4	Completion of 1 PhD student	30 Jun 2018	In Progress
R3.7.5	Completion of 3 PhD students	30 Jun 2019	In Progress

Performance against activities, continued.

Publications list in 2018–19

In the past 12 months, a total of 30 publications were produced across the Centre's industry-led and PhD scholarship projects – publication details are listed below:

Book chapters

Ngo, N.T. and Indraratna, B. (2019). Interface behavior of geogrid-reinforced sub-ballast: Laboratory and discrete element modeling. *Lecture Notes in Civil Engineering*, 29: 195-209.

Articles in scholarly refereed journals

Bernal, E., Spiryagin, M. and Cole, C. Onboard condition monitoring sensors, systems and techniques for freight railway vehicles: a review. *IEEE Sensors Journal* (Volume: 19 , Issue: 1 , Jan.1, 1 2019)

Fallahnezhad, K., Liu, S., Brinji, O., Marker, M. and Meehan, PA. (2019). Monitoring and modelling of false brinelling for railway bearings, *Wear*, Volumes 424- 425, 2019, Pages 151-164.

Indraratna, B, Qi, Y, Ngo, TN, Rujikiatkamjorn, C, Neville, T, Ferreira, FB & Shahkolahi, A 2019, 'Use of Geogrids and Recycled Rubber in Railroad Infrastructure for Enhanced Performance', *Geosciences*, vol. 9, no. 1, p. 30.

Jayasuriya, C., Indraratna, B. and Ngo, T.N. (2019). Experimental study to examine the role of under sleeper pads for improved performance of ballast under cyclic loading. *Transportation Geotechnics*, 19, pp: 61-73.

Li N., Yang L., Li X.D., Li X., Tu J.Y., Cheung C.P. Multi-objective optimization for designing of high-speed train cabin ventilation system using particle swarm optimization and multi-fidelity Kriging. *Building and Environment*, 155 (2019): 161-174.

Lin, CL and Meehan, PA. (2019). Microstructure Characterization of Degraded Grease in Axle Roller Bearings, *Tribology Transactions*, 62(4), (2019) 667-687

Ngo, N.T., Indraratna, B. and Rujikiatkamjorn, C. (2019). Improved performance of ballasted tracks under impact loading by recycled rubber mats. *Transportation Geotechnics*, 20, A 100239.

Saki, M., Abolhasan, M. and Lipman, J. (2019). A Novel Approach for Big Data Classification and Transportation in Rail Networks. *IEEE Transactions on Intelligent Transportation Systems*. *IEEE Transactions on Intelligent Transportation Systems*, 29 April 2019, pp. 1 – 11.

Shrestha, S., Wu, Q. and Spiryagin, M. (2019). Review of adhesion estimation approaches for rail vehicles, *International Journal of Rail Transportation*, 7:2, 79-102

Zhang, Y., Alarco, J., Best, AS., Snook, GA., Talbot, PC. And Nerkar, JY. (2019). Re-evaluation of experimental measurements for the validation of electronic band structure calculations for LiFePO₄ and FePO₄. *RSC Advances*, 2019, 9, 1134

Zhao, S., Sun, B., Yan, K., Zhang, J., Wang, C. and Wang, G., (2018), Aegis of Lithium-Rich Cathode Materials via Heterostructured LiAlF₄ Coating for High-Performance Lithium-Ion Batteries, *ACS Applied Materials & Interfaces* 2018 10 (39), 33260-33268

Zhou, D., Tkacheva, A., Tang, X., Sun, B., Shanmukaraj, D., Li, P., Zhang, F., Armand, M., and Wang, G., (2019), Stable Conversion Chemistry-Based Lithium Metal Batteries Enabled by Hierarchical Multifunctional Polymer Electrolytes with Near-Single Ion Conduction, *Angewandte Chemie International Edition*, 2019, 58 18, pp: 6001-600

Conference papers – refereed proceedings

Bernal, E., Cole, C. and Spiryagin, M. (2019) Innovative sensor-node hardware architecture for on-board heavy haul wagon monitoring. In Larsson-Kraik, P.O. (Ed), Ahmadi, A. (Ed.), *Proceedings of the International Heavy Haul Association STS Conference (IHHA 2019)* (pp. 705-712). Narvik, Norway.

Huang, H., Xu, J., Zhang, J., Wu, Q. and Kirsch, C. (2018). Railway Infrastructure Defects Recognition using Fine-grained Deep Convolutional Neural Networks. *2018 Digital Image Computing: Techniques and Applications (DICTA)*, Canberra, Australia, 2018, pp. 1-8.

Huang, H., Zhang, J., Zhang, J., Wu, Q. and Xu, J. (2019). Compare More Nuanced: Pairwise Alignment Bilinear Network for Few-Shot Fine-Grained Learning. *2019 IEEE International Conference on Multimedia and Expo (ICME)*, Shanghai, China, 2019, pp. 91-96.

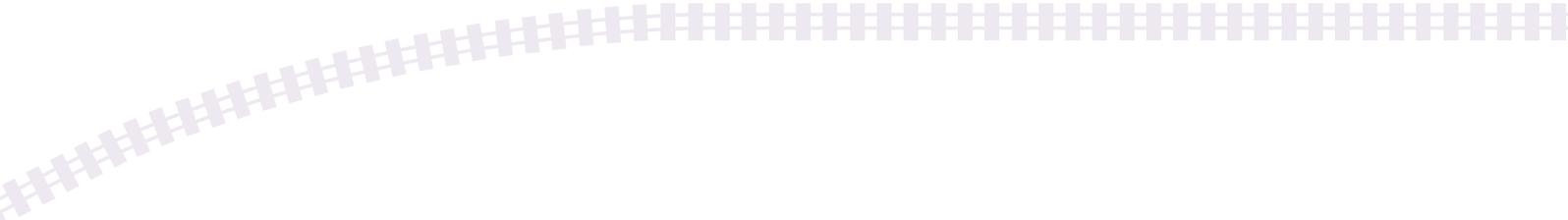
Indraratna, B., Ferreira, F.B., Qi, Y. & Sun, Q. (2018). The role of energy absorbing materials in heavy haul rail for minimising track degradation, *4th International Conference on Railway Technology: Research, Development and Maintenance*, Barcelona, Spain, September 2018.

Indraratna, B., Ngo, N.T and Ferreira, F. (2019). Advancements in Track Technology: Use of Artificial inclusions for stabilising Transport Infrastructure. *13th Australia New Zealand Conference on Geomechanics (ANZ2019)*, pp. 1-6, Perth, WA, April 2019.

Indraratna, B., Ngo, N.T and Rujikiatkamjorn, C. (2018). Advancement in track technology - composite foundations for increased speed and axle loads. *Conference on Railway Excellence (CORE2018)*, pp. 442-451. United States: Informit.

Indraratna B., Ngo N.T., Sun Q., Rujikiatkamjorn C., Ferreira F.B. (2019). Concepts and Methodologies for Track Improvement and Associated Physical Modelling and Field Monitoring. In: Sundaram R., Shahu J., Havanagi V. (eds) *Geotechnics for Transportation Infrastructure. Lecture Notes in Civil Engineering*, vol 28, Page: 219-246. Springer, Singapore.

- Li Z., Zhang J., Wu Q., Kirsch C. (2018) Field-Regularised Factorization Machines for Mining the Maintenance Logs of Equipment. In: Mitrovic T., Xue B., Li X. (eds) AI 2018: Advances in Artificial Intelligence. AI 2018. Lecture Notes in Computer Science, vol 11320. Springer, Cham
- Li, Z., Zhang, J., Wu, Q., Gong, Y., Yi, J. and Kirsch, C. (2019). Sample Adaptive Multiple Kernel Learning for Failure Prediction of Railway Points. 25th ACM SIGKDD Conference on Knowledge Discovery and Data Mining, 2019KDD '19 Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining
- Lin, CL. and Meehan, P. (2018). Study Of Wear Debris In Grease-Lubricated Axle Bearings Using Sem/Edx Analytical Technique. Proceedings of the 11th International Conference on Contact Mechanics and Wear of Wheel/Rail Systems, Delft, the Netherlands, 24-27 September 2018.
- Liu, C., Ngo, N. & Indraratna, B. (2018). Improved performance of railroad ballast using geogrids. Proceedings of the International Symposium on Geotechnics of Transportation Infrastructure (ISGTI 2018) (pp. 443-448). India: Indian Institute of Technology Delhi.
- Liu, W., Chen, BK. and Pang, Y. (2018). A new temperature-dependent anisotropic constitutive model for predicting deformation and spring-back in warm deep drawing of automotive AA5086-H111 aluminium alloy sheet. The International Journal of Advanced Manufacturing Technology August 2018, Volume 97, Issue 9–12, pp 3407–3421.
- Randeniya, N., Ranjha, S., Kulkarni, A. and Lu, G. (2019). Virtual Reality Based Maintenance Training Effectiveness Measures – a Novel Approach for Rail Industry. 2019 IEEE 28th International Symposium on Industrial Electronics (ISIE), Vancouver, BC, Canada, 2019, pp. 1605-1610.
- Ravitharan, R., Chevin, J., Chung, H., Vong, CH. and Zhang, D. (2019) The Implementation of Unmanned Autonomous Systems (UAS) for Rail Inspection. In Larsson-Kraik, P.O. (Ed), Ahmadi, A. (Ed.), Proceedings of the International Heavy Haul Association STS Conference (IHHA 2019). Narvik, Norway.
- Saki, M., Abolhasan, M. and Lipman, J. (2019). A big sensor data offloading scheme in rail networks. In 2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring), pp. 1–6, April 2019.
- Shrestha, S., Wu, Q., & Spiriyagin, M. (2018). Wheel-rail contact modelling for real-time adhesion estimation systems with consideration of bogie dynamics. In Z. Li & A. Núñez (Eds.), 11th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems (pp. 862–869). Delft, The Netherlands.
- Su, H., Pun, CL., Mutton, P., Kan, Q. and Yan, W. (2018). Numerical study on the ratcheting performance of heavy haul rails in curved tracks. In 11th International Conference on Contact Mechanics and Wear of Rail/wheel Systems, CM 2018 (pp. 938-947). Delft, The Netherlands.



Education and training

The Rail Manufacturing CRC has continued its commitment to delivering a strong education program by supporting its students to consider future employment in Australia's rail industry.

In the past 12 months, the number of PhD students supported by the Centre has risen to a high of 48 students commencing across the Centre's industry projects, PhD scholarships and rail industry internships.

Industry projects

As of 30 June 2019, there are 12 students actively working on industry projects:

- » Tianyi Wang and Shuoqing Zhao, both working on Project R1.1.1 - ***New generation lithium-ion batteries with high energy and long service life for rail industry applications*** (HEC Group / University of Technology Sydney)
- » Pauline Jaumaux, Xiaochun Gao and Yi Chen, all working on Project R1.1.2 - ***Hybrid supercapacitors with high energy and power densities for rail industry applications*** (HEC Group / University of Technology Sydney)
- » Zhang Yin, working on Project R1.3.3 - ***High energy supercapacitor development*** (CRRC / CSIRO), studying at Queensland University of Technology
- » Matthew Pozzebon and Abdul Mannan, both working on Project R2.3.2 - ***Axle bearing maintenance optimisation*** (Bombardier / University of Queensland)
- » Osama Brinji and Vijayaragavan Raju, both working on Project R2.3.4 - ***Monitoring and control of false brinelling*** (Bombardier / University of Queensland)
- » Alexander Virgona and Julien Collart, both working on Project R3.1.2 - ***Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system*** (Downer / University of Technology Sydney)

Chaminda Jayasuriya, who worked on Project R2.5.1 - ***Performance of recycled rubber inclusions for improved stability of railways*** (Tyre Stewardship Australia / Australasian Centre for Rail Innovation / University of Wollongong) submitted her PhD thesis in March 2019 and is now employed as a Research Associate at the University of Wollongong.



PhD Students' Forum attendees in March 2019

PhD scholarships

Since establishing its scholarship program in 2016–17, the Centre has grown its number of PhD student scholarship recipients, with 30 students now actively working on their PhDs.

The scholarships have been granted to select students working in rail research relating to one of the Centre's three key research areas – Power and Propulsion, Materials and Manufacturing, and Design, Modelling and Simulation.

These scholarships are co-funded by the Rail Manufacturing CRC and the student's respective university. Universities participating in the scholarship program include CQUniversity, Swinburne University, RMIT University, Monash University, University of Wollongong and the University of Technology Sydney.

Industry internships

Across 2016–17 and 2017–18, the Rail Manufacturing CRC and TrackSAFE Foundation delivered a PhD internship program, where two PhD students from Queensland University of Technology participated in a 12-week paid level crossing-related internship with rail organisations Queensland Rail and Aurizon.

One of the interns, Zheshuo Zhang, has since completed his PhD thesis in April 2019 and is now actively looking for employment in Australia's rail industry.

Encouraging the next generation of rail employees

With an ever-increasing number of students supported by the Centre, the Rail Manufacturing CRC has continued to deliver ongoing support and guidance to its student cohort.

In March 2019, the Centre hosted its second annual PhD Students' Forum in Melbourne. The forum provided two full days for the students to build relationships, learn more about Australia's rail industry and to participate in professional development activities.

The second day introduced the Grow Your Career program, a combined face-to-face and webinar training program delivered across 2019 to upskill students to understand their personality preferences, career goals and drivers, and to develop strong LinkedIn profiles, resumes and interview career readiness skills to prepare to find work in Australia's rail industry after graduation.

In addition to this program, the students have further been supported through:

- » Industry tours of rail headquarters and job sites
- » Participation in and presentations at key rail and industry events
- » Ongoing training support and guidance



Student workshopping underway



Student tour at Downer Newport depot



Terence Vu and Esteban Bernal attending AusRAIL 2018

Key student successes

With many students now well progressed into their PhD research, a number of students have been recognised, including:

- » Monash University PhD student Wenhua Jiang was awarded a Graduate Research International Travel Award (GRITA) by her university, receiving \$10,000 for collaborative research. The prize money will be used by Wenhua to spend six months at Massachusetts Institute of Technology (MIT) continuing her research in passenger flow forecasting, starting in August 2019.
- » University of Wollongong PhD student Chuhao Liu was selected as one of six finalists for the 2019 TEDxSydney Kick Start competition. Chuhao delivered a one-minute pitch in the final for a concept called SoundTrack – involving processing audio data of the wheel on the track to monitor conditions in real time. This idea is separate to his PhD research topic on the use of geogrids for ballast stability, for which he won pitching awards in the CRC Association and 3MT competitions in 2018.

Status against milestones

There are seven active education-related milestones, three of which have been Achieved and four are In Progress.

Student milestones for 2018–19 now focus on the completion of PhDs, which the Centre defines as the point in which the student submits their PhD thesis for assessment. To-date, two PhD students have completed their PhDs in Research area 2 – Materials and Manufacturing.

The delay in achieving PhD completion milestones is due to the time taken to establish a comprehensive PhD scholarship program following a lack of initial industry projects with opportunities for PhD students. With most PhD scholarship students commencing in 2016–17 and 2017–18, this will result in increasing PhD completions occurring in 2019–20, followed by a mass number of completions in the 2020–21 Financial Year.

In response to current milestones:

- » **For Milestone R1.5.4:**
The first student in the Power and Propulsion research area is due to submit their thesis in January 2020, followed by two students submitting in February 2020.
- » **For Milestone R2.5.5:**
Two students in the Materials and Manufacturing research area have submitted their theses, with further students due to submit in October 2019 and July 2020.
- » **For Milestones R3.7.4 and R3.7.5:**
Students are scheduled to submit their theses in October 2019, January 2020, June 2020 and July 2020.

Milestone number	Milestone	Due date	Status
Program 1 – Power and Propulsion			
R1.5.2	Commencement of 4 PhD students	30 Jun 2017	Achieved
R1.5.3	Commencement of 3 PhD students	30 Jun 2018	Achieved
R1.5.4	Completion of 1 PhD student	30 Jun 2019	In Progress
Program 2 – Materials and Manufacturing			
R2.5.4	Completion of 1 PhD student	30 Jun 2018	Achieved
R2.5.5	Completion of 3 PhD students	30 Jun 2019	In Progress
Program 3 – Design, Modelling and Simulation			
R3.7.4	Completion of 1 PhD student	30 Jun 2018	In Progress
R3.7.5	Completion of 3 PhD students	30 Jun 2019	In Progress

Education and training, continued.

Current list of commenced PhD students – as of 30 June 2019

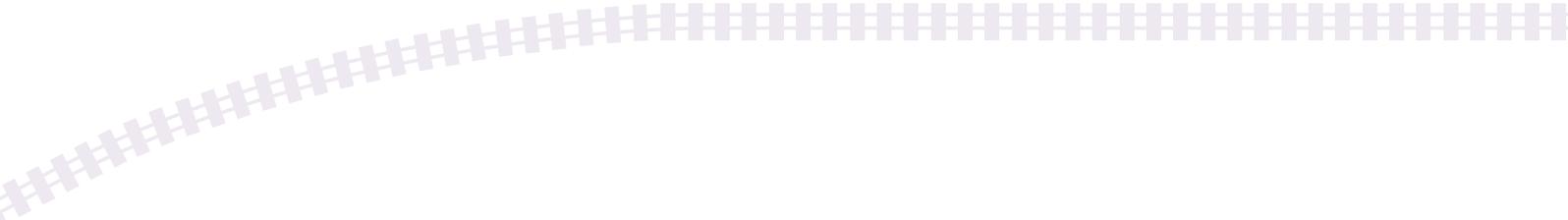
#	Student name	Degree	Start date	Expected completion date	Project title	Research institute	Student's country of origin
Program 1 – Power and Propulsion							
1	Tianyi Wang	PhD	25/08/2017	August 2021	New generation lithium-ion batteries with high energy and long service life	University of Technology Sydney	China
2	Shuoqing Zhao	PhD	22/08/2017	August 2021	New generation lithium-ion batteries with high energy and long service life	University of Technology Sydney	China
3	Pauline Jaumaux	PhD	20/08/2018	August 2022	Hybrid supercapacitors with high energy and power densities for rail industry applications	University of Technology Sydney	Belgium
4	Xiaochun Gao	PhD	26/08/2016	February 2020	Hybrid supercapacitors with high energy and power densities for rail industry applications	University of Technology Sydney	China
5	Yi Chen	PhD	26/08/2016	February 2020	Hybrid supercapacitors with high energy and power densities for rail industry applications	University of Technology Sydney	China
6	Zhang Yin (Yin)	PhD	2/05/2016	January 2020	High energy supercapacitor development	Queensland University of Technology	China
7	Sundar Shrestha	PhD	03/07/2017	July 2021	Estimation of adhesion conditions between wheels and rails for the development of advanced braking control systems	CQUniversity	Nepal
8	Esteban Bernal Arango	PhD	03/07/2017	July 2021	Smart axle transducer transmitter for freight wagon condition monitoring systems	CQUniversity	Colombia
9	Minoo Oveisi	PhD	24/10/2018	October 2022	A static and dynamic loading assessment of structural-critical composite material rolling stock carbody shells	RMIT University	Iran
Program 2 – Materials and Manufacturing							
10	Cameron Milne	PhD	12/01/2015	N/A ¹	Axle-bearing maintenance optimisation	University of Queensland	Australia
11	Matthew Pozzebon	PhD	28/04/2016	October 2019	Axle-bearing maintenance optimisation	University of Queensland	Australia
12	Abdul Mannan (Mannan)	PhD	01/07/2018	July 2022	Axle-bearing maintenance optimisation	University of Queensland	Bangladesh
13	Osama Brinji	PhD	13/04/2017	July 2020	Monitoring and control of false brinelling	University of Queensland	Saudi Arabia
14	Vijayaragavan Raju (Vijay)	PhD	01/07/2018	June 2022	Monitoring and control of false brinelling	University of Queensland	India
15	Chamindi Jayasuriya	PhD	22/08/2014	Completed	Performance of recycled rubber inclusions for improved stability of railways	University of Wollongong	Sri Lanka
16	Chuhao Liu	PhD	18/04/2017	October 2020	The performance of stabilised ballast in rail tracks	University of Wollongong	China
17	Mahsa Taherimandarjani	PhD	30/04/2018	April 2022	Laboratory evaluation of laser cladding on rail wheel steels	Swinburne University of Technology	Iran
18	Meng Wang	PhD	25/01/2018	January 2022	Manufacturing of lightweight panels	Swinburne University of Technology	China
19	Fukun Xia	PhD	15/12/2017	December 2021	Evaluation of hybrid structures for impact performance in rail applications	Swinburne University of Technology	China
20	Vu Trong Thien (Terence)	PhD	27/02/2017	August 2020	Automated assembly for rolling stock fabrication in rail industry	University of Wollongong	Vietnam
21	Hang Su	PhD	27/02/2017	September 2020	Optimisation of rail welding process parameters to mitigate rolling contact damage	Monash University	China
22	Pravin Urudra	PhD	01/03/2017	N/A ²	Evaluating the suitability of laser clad rail steel in heavy haul application	Monash University	Malaysia
23	Simon Wagner	PhD	14/05/2018	May 2022	Heavy haul train force control product	CQUniversity	Australia
24	Elias Salloum	PhD	01/03/2018	February 2022	Optimising friction-stir welding and alloy design to ensure the durability of light weight carriages in the rail fleet	RMIT University	Australia
25	Mohammad Adinehrand	PhD	14/11/2018	November 2022	Miniature crawling robots for rolling stock manufacture and maintenance	RMIT University	Iran

^{1,2} This student withdrew from his PhD

#	Student name	Degree	Start date	Expected completion date	Project title	Research institute	Student's country of origin
Program 2 – Materials and Manufacturing							
26	Anthony Micheletto	PhD	04/01/2018	April 2021	Improvement of flashbutt welds in premium rails	Monash University	Australia
27	Tommy Huynh	PhD	10/12/2018	December 2022	Fire-retardant and lightweight composite materials for rolling stock carriages	RMIT University	Australia
28	Panahsadat Fasihi	PhD	14/08/2018	November 2021	Full-scale implementation of a new wheel-rail maintenance technology by using laser cladding	Monash University	Iran
29	Don Kushlani Ranmal Ranasinghe	PhD	27/06/2016	N/A ³	Optimal design of raised rail - road crossing structure	Queensland University of Technology	Sri Lanka
30	Zheshuo Zhang	PhD	17/11/2015	Completed	Effect of raised rail - road crossing to the safety of road vehicles	Queensland University of Technology	China
Program 3 – Design, Modelling and Simulation							
31	Alexander Virgona	PhD	29/08/2014	October 2019	Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system	University of Technology Sydney	Australia
32	Julien Collart	PhD	05/02/2015	January 2020	Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system	University of Technology Sydney	France
33	Mahdi Saki	PhD	02/02/2016	September 2023	Ultra-reliable and cost effective communication infrastructure for future IoT-based railway applications	University of Technology Sydney	Iran
34	Zhibin Li	PhD	02/03/2017	March 2021	Big data analytics for condition based monitoring and maintenance	University of Technology Sydney	China
35	Huaxi Huang	PhD	03/04/2018	April 2022	Rail infrastructure defect detection through video analytics	University of Technology Sydney	China
36	Amir Eslami	PhD	05/06/2017	N/A ⁴	Drive-by bridge inspection: the use of instrumented revenue wagons for structural health monitoring of rail bridges	Monash University	Iran
37	Yu Fung Lee (Joseph)	PhD	27/02/2017	June 2020	Nonlinear vibro-acousto-ultrasonic waves for fatigue cracking detection in key rail components	Monash University	China
38	Chi Hei Vong (Calvin)	PhD	27/02/2017	July 2020	Control and navigation of micro UAV in small railway culverts and tunnels	Monash University	Portugal
39	Yong Pang	PhD	30/05/2017	August 2020	System for real-time monitoring and sensing railway conditions by laser light	Monash University	China
40	Dongyu Zhang	PhD	01/03/2017	October 2020	Hybrid unmanned aerial system for railway inspection	Monash University	China
41	Nalin Randeniya	PhD	15/06/2017	June 2021	Train maintenance training enhancements with transformative technologies for productivity and quality measures	Swinburne University	Sri Lanka
42	Andrew Danylec	PhD	15/06/2017	June 2021	Develop and establish augmented reality tools in High Capacity Metro Train for productivity and quality enhancements	Swinburne University	Australia
43	Wenhua Jiang	PhD	17/10/2017	January 2021	Short-term rail passenger flow forecasting application	Monash University	China
44	Don Skerman	PhD	22/10/2018	October 2022	Efficient daily track monitoring system	CQUniversity	Australia
45	Jie Yang (Joanne)	PhD	22/06/2018	June 2022	Optimising railway carriage design for improved dispersion, capacity and safety	RMIT University	Australia
46	Bibek Baral	PhD	09/10/2018	October 2021	FEM modelling of vacuum consolidation to alleviate visco-plastic strains in soft subgrade soils	University of Wollongong	Nepal
47	Peter Allen	PhD	31/08/2018	August 2021	Impeding pedestrian-train collisions using safety by design principles	Swinburne University	Australia
48	Alejandro Tamani	PhD	22/11/2018	November 2022	Development of evacuation management tool for rail transport	RMIT University	Australia

³ This student withdrew from her PhD

⁴ This student withdrew from his PhD and reverted to Masters



SME engagement

As small-to-medium enterprises (SMEs) comprise a large majority of Australia's rail manufacturing and maintenance sector, these organisations are an important factor of the rail industry, and a key segment for the Rail Manufacturing CRC to engage with.

Not all SMEs have the capacity or financial means to become Participants in the Rail Manufacturing CRC. Therefore, the Centre looks at each research program theme and individual project to see how SME involvement can best be incorporated.

Effectively working with these businesses is a key to the Rail Manufacturing CRC's success, and the Centre continues to work with numerous SMEs to keep them informed of activities. When SME organisations are participating directly in activities, the Centre also works with them to ensure the organisation's needs are being met.

The Centre's SME engagement included the following activities in 2018–19:

- » Delivery of two Rail Manufacturing CRC Participants Forums during the year
- » Direct engagement with the Centre's CEO and key staff through participation in rail industry events and forums – including key rail conferences, rail peak body events and Federal and State Government forums
- » Regular communication about the Centre's activities and progress through the Rail Manufacturing CRC's monthly email newsletters, website and social media updates, and face-to-face meetings.



Current Engagements with SMEs

During the reporting period, the Rail Manufacturing CRC had seven SMEs Participants, with four SMEs participating with the Centre in active projects:

Project R2.5.2 - **Application of geogrids for minimising track deformation and degradation under high frequency cyclic and heavy haul loading** (Global Synthetics / Foundation QA / University of Wollongong):

Global Synthetics and Foundation QA are involved in the implementation of technologies to solve unique challenges involving rail ballast infrastructure. A series of large-scale tests are currently in progress to investigate the behaviour of the rail ballast with and without geogrid reinforcement under cyclic loading conditions. Simulations results have shown that the geogrid can significantly reduce the deformations of ballast under these loading conditions.

Project R3.3.2 - **Development of a smart rail route map** (Australasian Railway Association / Deakin University):

The delivery of a framework whereby industry agreed goals and future challenges for the rail sector were mapped out over the coming decades related to adopting new digital and communication technologies. The Smart Rail map will be used to assist industry to implement the recommendations provided in the report.

Project R3.6.1 - **Experimental and computational study on the key ventilation issues affecting air quality and thermal comfort in train cabins** (Airlinx / RMIT University):

Airlinx is deriving a greater understanding of its ventilation products through long-term modelling and simulation research being undertaken in collaboration with RMIT University. In this project, commercial software has been used to develop a computational fluid dynamics model for assisting ventilation designs.



Commercialisation

The Rail Manufacturing CRC's model for commercialisation and utilisation was developed in close consultation with its Industry and Research Participants, with an overarching principle to support and facilitate industry-led research outcomes in an independent manner.

This model is tailored to each project and is dependent on factors, including the:

- » capacity of the Participants to use and commercialise project outcomes
- » research and commercial inputs to the project
- » benefit to Australia
- » contributions of parties to intellectual property
- » commercial viability of the research outcomes.

With the Centre playing an independent role in project decision making, the commercialisation model limits the number of organisations seeking input into commercial decisions, ensuring that Industry and Research Participants investing in the project will receive benefit from any commercial returns.

Before projects commence, all commercial outcomes and Intellectual Property (IP) terms and conditions are determined through transparent contractual negotiations, which limits any potential IP legacy issues in future years.

Projects completed

As of June 2019, four Rail Manufacturing CRC projects were completed during the year:

- » Project R1.3.3 - **High energy supercapacitor development** (CRRC / CSIRO) has resulted in the production of a supercapacitor with good cycle life and power that still maintains sufficient energy density. Further work may be required to improve the electronic conductivity of the device
- » Project R2.3.2 - **Axle bearing maintenance optimisation** (Bombardier / University of Queensland) involved the development and testing of a new optimised predictive maintenance system for bearings. This work has enabled Bombardier to progress commercial activities in optimising axle bearing maintenance
- » Project R3.3.2 - **Development of a smart rail route map** (Australasian Railway Association / Deakin University) provides a framework for improving the industry's ability to adopt and keep pace with telecommunication and information-based technologies and endeavours to improve standardisation, integration and harmonisation over the next 30 years
- » Project R3.5.1 - **Battery HVAC feasibility study** (Knorr-Bremse / CSIRO) enables Knorr-Bremse and CSIRO to undertake future activities in heating, ventilation and air-conditioning battery use with much deeper insights into the background technology involved.



Project development at CSIRO

Project extensions

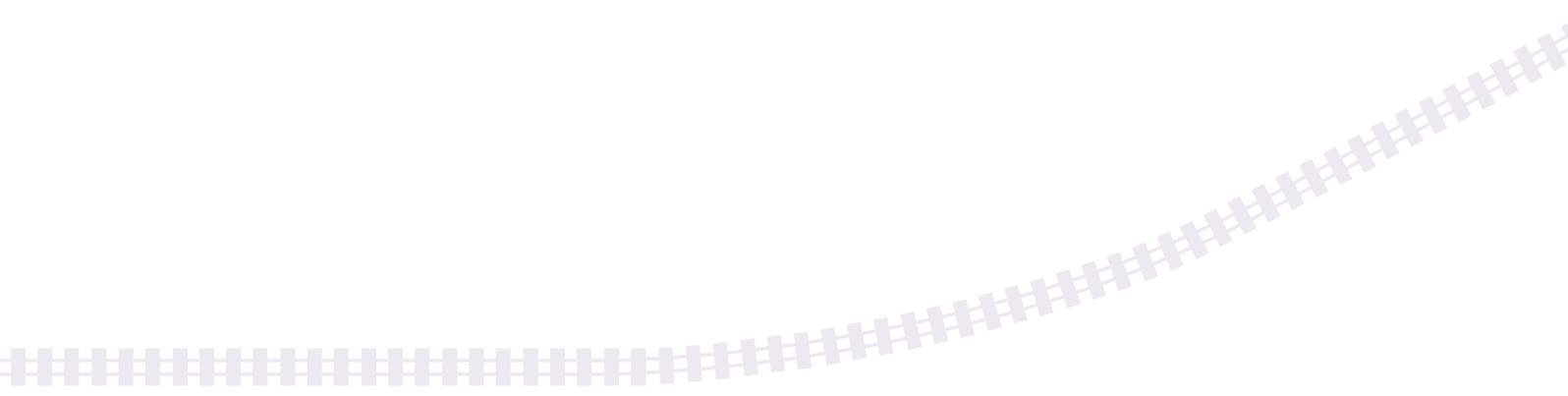
Project R3.1.2 - ***Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system*** (Downer / University of Technology Sydney) was extended to conduct a trial of the technology to take place in conjunction with Sydney Trains. The trial, commencing in August 2019, involves the installation of Dwell Track™ technology to monitor the movement of passengers on and off trains.

Project R3.3.2 - ***Development of a smart rail route map*** (Australasian Railway Association / Deakin University) was also extended to broaden its scope to include new milestones to support the map's implementation.

Commercialisation, continued.

Utilisation milestones

Milestone number	Milestone	Due date	Status
Program 1 – Power and Propulsion			
U1.3.2	Evaluation in the field by an end user	30 Jun 2019	Achieved
U1.4.1	Grant of Utilisation rights to Industry Participant	30 Jun 2019	Achieved
Program 2 – Materials and Manufacturing			
U2.1.3	Evaluation by an end user	31 Dec 2018	Achieved
U2.1.4	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U2.1.5	Assignment of Project IP	30 Jun 2019	Achieved
U2.2.2	Further development and scale up of rolling stock maintenance cost reduction technology completed	30 Dec 2018	Achieved
U2.2.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U2.2.4	Assignment of Project IP	30 Jun 2019	Achieved
U2.3.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U2.3.4	Assignment of Project IP	30 Jun 2019	Achieved
U2.4.2	Evaluation of Substructures for reduced vibration and enhanced stability	31 Dec 2018	Achieved
U2.4.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U2.4.4	Assignment of Project IP	30 Jun 2019	Achieved
Program 3 – Design, Modelling and Simulation			
U3.1.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U3.1.4	Assignment of Project IP	30 Jun 2019	Achieved
U3.2.2	Further development and scale up of advanced detection technologies completed	30 Jun 2019	Achieved
U3.2.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U3.2.4	Assignment of Project IP	30 Jun 2019	Achieved
U3.3.2	Up take by Industry of further development and scale up of software and hardware incorporating the algorithms	30 Jun 2019	Achieved
U3.4.1	Grant of Utilisation rights to Industry Participant	30 Jun 2019	Achieved
U3.4.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved
U3.4.4	Assignment of Project IP	30 Jun 2019	Achieved
U3.6.3	Grant of Utilisation rights to R&D Participant	30 Jun 2019	Achieved



Intellectual property management

The Rail Manufacturing CRC Ltd is a company limited by guarantee, meaning it has members rather than shareholders.

The Centre has always focused on transferring the intellectual property that results from projects in the most effective manner to its Participants and to ensure maximum benefit and impact are derived.

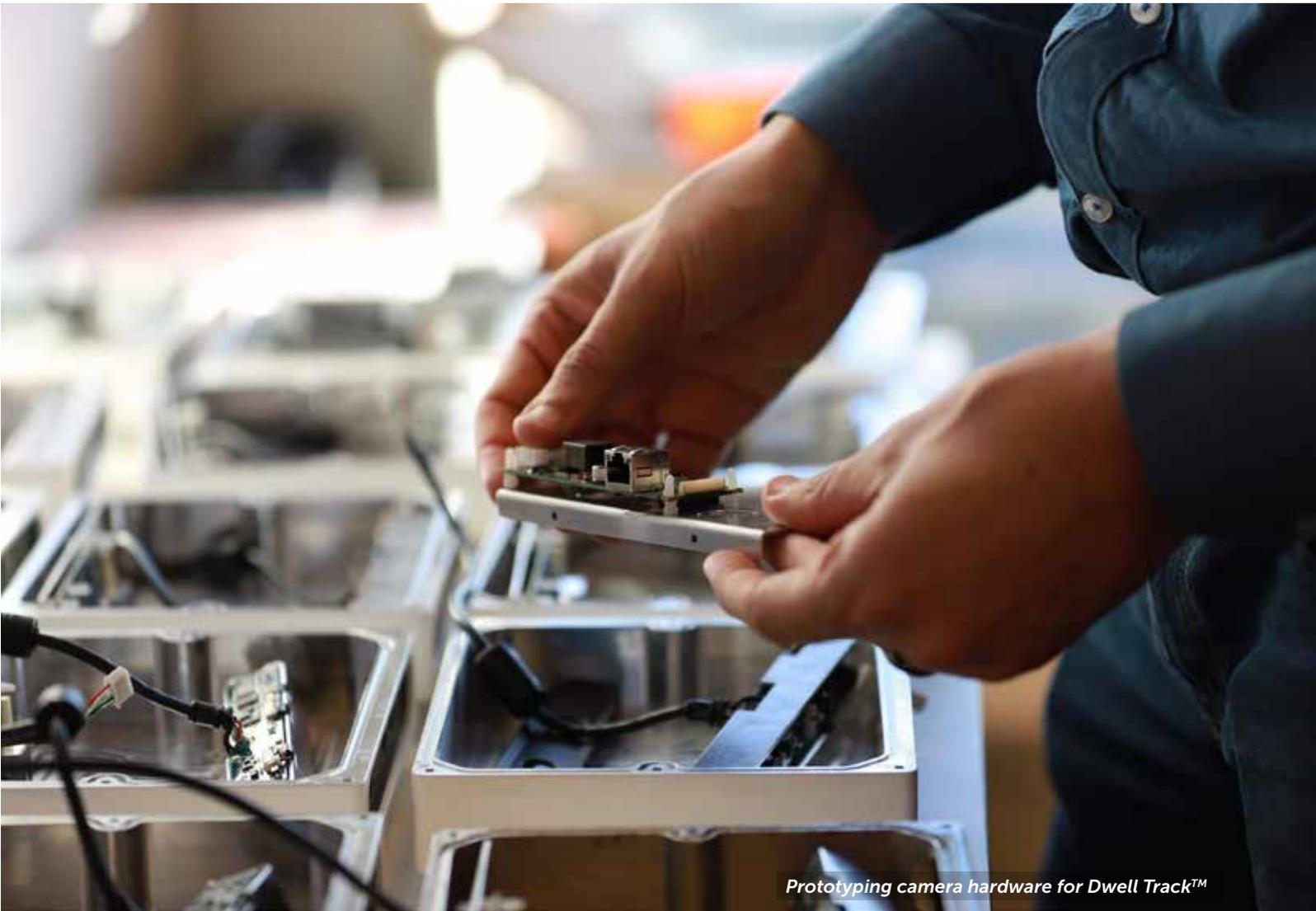
The Rail Manufacturing CRC does not seek to own intellectual property nor seek royalties from the technology it develops. Instead, the Centre works to ensure that the technologies its projects deliver will provide the maximum benefit to project partners.

Ownership and use of the project intellectual property is defined during the development of individual project agreements between the respective project Participants to ensure that the process is transparent and beneficial to all parties.

Patent published

On 13 June 2019, an International Patent Application was published relating to Project R3.1.2 - ***Integrated passenger behaviour, train operations, diagnostics and vehicle condition monitoring system*** (Downer / University of Technology Sydney):

Application number	Title	Priority data	Applicants
PCT/AU20 18/05 1303	Monitoring systems, and computer implemented methods for processing data in monitoring systems, programmed to enable identification and tracking of human targets in crowded environments	2017904919 06 December 2017 AU	University of Technology Sydney Downer EDI Rail Pty Ltd



Prototyping camera hardware for Dwell Track™

Communications

Effective communication is considered a fundamental element of the Rail Manufacturing CRC by the entire Management team, with a commitment to engage with stakeholders, build relationships, connect organisations together and support collaboration across the rail industry.

The Rail Manufacturing CRC's Communications program works to:

- » provide internal and external stakeholders with timely, consistent and informative communications about the Rail Manufacturing CRC's direction and activities
- » maintain strong and collaborative relationships with the Centre's Industry and Research Institute Participants and key external stakeholders
- » regularly evaluate the communication channels used via surveys, feedback, website analytics, social media engagement and newsletter readership.

During 2018-19, the Centre:

- » hosted one face-to-face Melbourne Participants Forum and one phone forum
- » ran its second annual PhD students' forum and delivered a webinar career readiness training program for students across four months
- » received a CRC Association award in May 2019
- » held regular project meeting and strategy planning sessions with Participants organisations
- » held its third annual Participants Survey
- » participated in a wide number of rail-focused sessions, including InnoTrans 2018, AusRAIL 2018, the ARA Technology and Telecommunications Forum, Inland Rail Summit 2019 and the Engineers Australia Transport 2056 Roundtable.



Smart Rail panel discussion at AusRAIL 2018

Rating the effectiveness of the Centre

The third annual Participants Survey was conducted in July to rate the effectiveness of the Centre in 2018–19. A link to an online survey was sent to one key representative per active Participant organisation, with 21 organisations in total asked to rate the Centre’s activities across a variety of functions.

The survey achieved a response rate of 71 per cent, with 15 organisations participating.

In summary:

Questions (where 1 = very unsatisfied, 3 = neutral, 5 = very satisfied)	Weighted Averages		
	2018-19	2017-18	2016-17
... the Centre’s Board is effective	4.43	4.33	3.67
... the Centre’s Senior Leadership is effective	4.60	4.61	4.00
... administration is effectively managed	4.53	4.39	4.21
... research programs are effectively managed	4.60	4.44	4.08
... project outcomes meet the expectations of Participants	4.33	4.06	3.71
... communications program is effectively managed	4.33	4.44	4.07
... education and training program is effectively managed	4.00	4.36	3.64
... level of satisfaction with the Centre’s Intellectual Property Model	4.20	4.11	4.00
Overall level of satisfaction with the collaboration between your organisation and the Rail Manufacturing CRC	4.40	4.33	4.07

With the Centre’s wind-up in June 2020, this will be the last survey conducted, though feedback will be regularly sourced from Participants as transitional activities progress.

Alignment to CRC Program Branding

As required, all communications activities adhere to proper use of CRC Program Branding, as specified in the Funding Agreement. This has included the appropriate promotion of logos and inclusion of content used in presentations delivered, on printed communications collateral and online via the Centre’s website and social media channels.



Dr Stuart Thomson sharing project outcomes at AusRAIL 2018

Governance

The Rail Manufacturing CRC Limited ("RMCRC"; "Company"; "Centre") is a public company limited by guarantee, incorporated and domiciled in Australia. The Rail Manufacturing CRC is registered as a charity with the Australian Charities and Not-for-profits Commission.

As a registered charity, the Australian Taxation Office granted income tax exemption, a Fringe Benefits Tax rebate on capped employee fringe benefits and certain GST concessions to the Centre. As a result, no provision for income tax has been made in the Centre's financial accounts.

Directors' Meetings

The Rail Manufacturing CRC Board met five times during 2018–19:

27 August 2018, 21 November 2018, 21 February 2019, 8 April 2019 and 23 May 2019.

During the year ended 30 June 2019, the number of Board meetings held while each Director was in office and the number attended by each Director was as follows:

Name	Role	Key skills	Independent / Organisation	Appointed (Resigned)	A ⁵	B ⁶
Current Directors						
Paul Johnson	Chair	Executive management, R&D, engineering, business administration, transport industry expertise, experience as a non-executive director	Independent	31/10/2014	5	5
Bronwyn Constance	Independent Director	Financial management, business administration, manufacturing industry administration, experience as a non-executive director	Independent	31/10/2014	5	5
Stuart Thomson	Executive Director (CEO)	Business administration, executive management, IP, commercialisation, R&D, experience as an executive director	Rail Manufacturing CRC	20/03/2015	5	5
Michael Miller	Industry Nominee	Financial management, business administration, manufacturing industry administration, IT, experience as non-executive director	Downer EDI Rail	14/10/2015	5	5
Grant Stanley	Research Nominee	R&D, commercialisation, higher education expertise, experience as a non-executive director	Central Queensland University	14/04/2016	5	3
Michael McLellan	Industry Nominee	Manufacturing industry administration, commercialisation, M&A, experience as a non-executive director	Knorr-Bremse Australia	26/09/2016	5	5
Jasbir Tumber	Industry Nominee	Rail industry administration, maintenance and operations; engineering, business administration	Sydney Trains	21/11/2019	3	3

⁵ A = Number of meetings held while the Director held office

⁶ B = Number of meetings attended

The Board is responsible to its members and Participants for the company's performance. The Board's election, composition, function and responsibilities are set out in the company's Constitution and in the Participants Agreement.

The filling of casual director vacancies is the responsibility of the Remuneration and Nominations Board Committee as follows:

- » Nominee directors - nominations are sought from the relevant industry or research Essential Participants (EP's), such that only industry EP's may nominate candidates to replace industry nominee directors and only research EP's may nominate candidates to replace research nominee directors. Likewise, voting is by nominee type EP only.
- » Independent directors - nominations are sought from suitable candidates, always keeping in mind the need to ensure that, collectively, the directors have skills and experience across a constitutionally established minimum set of fields.

The Board sets the Rail Manufacturing CRC company strategy and performance targets, it reviews and approves all company policies and it oversees the implementation of procedures to ensure that the Management team meets the Board's objectives. The Board meets at least quarterly for scheduled meetings.

The Chair is an independent director, and the Company's Constitution requires that the Board include:

- » up to four persons elected by a vote of the Industry Essential Participants
- » up to one person elected by a vote of the Research Essential Participants
- » up to three independent non-executive directors elected by a vote of Essential Participants
- » the CEO.

At the Annual General Meeting ("AGM") held 21 November 2018, Jasbir Tumber was elected as a new Industry Nominee director. Two serving directors retired by rotation as required under the constitution. Both retiring directors were re-elected, namely Bronwyn Constance and Michael Miller.

Board



CHAIR - PAUL JOHNSON MBE

DIP AIRCRAFT DESIGN,
MSC (AIRCRAFT DESIGN), MAICD.
INDEPENDENT DIRECTOR
AND BOARD CHAIR SINCE
31 OCTOBER 2014.

CHAIR OF RESEARCH &
DEVELOPMENT AND
REMUNERATION & NOMINATIONS
BOARD COMMITTEES.



BRONWYN CONSTANCE

F CPA, FAICD, FCIS.
INDEPENDENT DIRECTOR
SINCE 31 OCTOBER 2014.
CHAIR OF AUDIT & RISK
BOARD COMMITTEE.



CEO - DR STUART THOMSON

BSC, BSC (HONS), PHD, GCTMLP,
GAICD.
EXECUTIVE DIRECTOR SINCE
20 MARCH 2015.
CHIEF EXECUTIVE OFFICER
SINCE 1 APRIL 2015.

MEMBER OF RESEARCH
& DEVELOPMENT BOARD
COMMITTEE.

**EXPERIENCE AND
EXPERTISE:**

After 22 years in the Royal Australian Navy, Paul joined General Electric (USA) as the Australian Manager of Business Development. He was later assigned to Singapore as the ASEAN countries Regional Director for Business Development and was promoted to regional President for South Asia and Australasia, with responsibility for business activities in 17 countries. In 2003 Paul was appointed as Managing Director and CEO of Lockheed Martin Australia, while also acting as Chairman of the Australian Industry Group's Defence Industry Executive Council.

Since retiring from Lockheed Martin in 2011, Paul has been involved as a director on the Boards of a number of institutions, currently including Director of Aerospace, Maritime and Defence and Security Foundation of Australia Limited (AMDSFA) and formerly a member of the Air Force Board and the Co-Chair Centre for Defence Industry Capability Advisory Board. Paul presently serves as an Independent Ministerial Advisor on Defence Innovation. He was awarded the MBE in 1980 in recognition of his contribution to the advancement of Naval Aircraft Engineering and is a Member of the Australian Institute of Company Directors.

**EXPERIENCE AND
EXPERTISE:**

Bronwyn has held many senior executive positions including Finance Director of Kraft Foods Limited Australia and New Zealand, Vice President Finance of Kraft Foods Asia, Executive General Manager Finance and Administration of Pasma Limited and Finance Director of Nylex Limited. She spent her early career with the ACI Group of companies. Bronwyn is a former independent director of the Melbourne Market Authority, Plantic Technologies Limited, The Just Group Limited, Colorpak Ltd, DMTC Ltd and the CRC for Advanced Automotive Technology.

**EXPERIENCE AND
EXPERTISE:**

Stuart received his PhD from the University of New South Wales (UNSW), and subsequently worked in various research roles at UNSW, the Max-Planck-Institut für Kohlenforschung and the Australian Nuclear Science and Technology Organisations (ANSTO). He has held numerous management roles in the manufacturing, mining, and agricultural sectors, including roles as Chief Operating Officer at CRC Mining and Executive Director and Board member of the Grape and Wine Research and Development Corporation. In 2015, he was appointed to the role of CEO and Managing Director of Rail Manufacturing CRC. He holds formal qualifications in Science, Trademark Law and Practice, and is a graduate of the Australian Institute of Company Directors.



MICHAEL MILLER

BEC, CA.

DIRECTOR SINCE
14 OCTOBER 2015
(INDUSTRY NOMINEE).

MEMBER OF AUDIT & RISK
AND REMUNERATION &
NOMINATIONS BOARD
COMMITTEES.



PROF GRANT STANLEY

BENG(CHEM), PHD.

DIRECTOR SINCE
14 APRIL 2016 (RESEARCH &
DEVELOPMENT NOMINEE).

MEMBER OF AUDIT &
RISK, REMUNERATION &
NOMINATIONS AND RESEARCH
& DEVELOPMENT BOARD
COMMITTEES.



MICHAEL MCLELLAN

BENG, POSTGRADDIP

DIRECTOR SINCE
26 SEPTEMBER 2016
(INDUSTRY NOMINEE).



JASBIR TUMBER

BENG (HONS)

DIRECTOR SINCE
21 NOVEMBER 2018
(INDUSTRY NOMINEE).

MEMBER OF AUDIT & RISK
BOARD COMMITTEE.

**EXPERIENCE AND
EXPERTISE:**

Michael joined Downer EDI Limited in 2011 and was appointed Group Head – Customer & Government Partnerships in January 2019. Prior to his current role, Michael has previously held the position of CEO Downer Rail and the CFO position for both Downer Rail and the Waratah Train Project. Prior to joining Downer, Michael held executive positions within the IT and Telecommunications industry, including Hewlett Packard and Nortel Networks. Michael is a Director of Downer EDI Rail and associated entities and a Director of the Australasian Railway Association.

**EXPERIENCE AND
EXPERTISE:**

Grant Stanley holds undergraduate and postgraduate degrees from the University of Melbourne and has a background in Applied Microbiology/Biochemical Engineering, with ongoing research interests in biofuel production. He has experience in research and teaching and has published over 110 scientific papers, an international patent, has received a number of Commonwealth and Industry funding grants and supervised 15 PhD students. Grant was the Head of Molecular Sciences at Victoria University, he then joined Central Queensland University Australia (CQUniversity) as the Dean of Medical and Applied Sciences. In 2013 he became the Pro Vice-Chancellor (Research) and is currently the Deputy Vice-Chancellor (Research) at CQUniversity. Grant has sat on a number of Boards including the SmartWater Research Board and Queensland Cyber Infrastructure Board, and is currently a member of the Advance Queensland Expert Panel.

**EXPERIENCE AND
EXPERTISE:**

Michael has been Managing Director of Knorr-Bremse Australia Pty Ltd since 2004. He is also a member of the Australasian Railway Association (ARA) board representing the Rail Industry Supplier group. Prior to joining Knorr-Bremse, Michael worked in a variety of management positions across organisations such as GUD Manufacturing, Honeywell and Caterpillar. He holds a Bachelor of Engineering, a Post Graduate Diploma in Marketing and is a Graduate member of the Australian Institute of Company Directors.

**EXPERIENCE AND
EXPERTISE:**

Jasbir was appointed Deputy Executive Director of Sydney Trains' Fleet Maintenance Division in July 2014, leading over 1000 employees in the maintenance and presentation of 12 fleet types across Sydney and NSW Trains. He has over 20 years of experience in delivering customer services within transportation across both the public and private sectors, from engineering, operations and maintenance through to engaging and influencing executive stakeholders to deliver business transformations.



Keeping the Centre on track

Committees

The **Audit and Risk Board Committee (ARBC)** is a subcommittee which reviews and provides recommendations to the Board on financial reporting, statutory audit functions, internal control functions, risk management, compliance and governance. The ARBC is chaired by an independent non-executive director and its membership currently includes two industry representative directors and a research provider representative director. The Committee met on four occasions in 2018–19 and the current members are:

- » Bronwyn Constance (Chair)
- » Grant Stanley (Research representative member)
- » Michael Miller (Industry representative member)
- » Jasbir Tumber (Industry representative member, appointed to committee 21 February 2019).

The **Research and Development Board Committee (RDBC)** is a subcommittee which reviews and provides recommendations to the Board on project proposals, project progress and expenditure. Membership of the RDBC consists of an independent, non-executive director as Chair and a research representative director. The Committee met on one occasion in 2018–19 and also considered other projects by means of circular resolutions. The current committee members are:

- » Paul Johnson (Chair)
- » Stuart Thomson (Managing Director)
- » Grant Stanley (Research representative).



The **Remuneration and Nominations Board Committee (RNBC)** assesses nominations for the Board and reviews remuneration of the Centre's Management and Independent Directors. The committee is chaired by an independent non-executive director and its membership includes an industry representative director and a research representative director. The Committee met on two occasions in 2018–19 and the current members are:

- » Paul Johnson (Chair)
- » Grant Stanley (Research representative)
- » Michael Miller (Industry representative).

The **Research and Development Management Committee (RDMC)** provides advice to the CEO on technical research areas and meets quarterly to discuss the Rail Manufacturing CRC's project portfolio with the appropriate Research and Industry Participant representatives. The Committee met on four occasions in 2018–19 and the current members are:

- » Larry Jordan (Chair, RMCRC Research Director)
- » Colin Cole (CQU, RMCRC Program Leader)
- » Paul Meehan (UQ, RMCRC Program Leader)
- » Stuart Thomson (RMCRC CEO).

Management team



CEO - DR STUART THOMSON

BSC, BSC(HONS), PHD, GCTMLP, GAICD.
CHIEF EXECUTIVE OFFICER SINCE APRIL 2015.

EXPERIENCE AND EXPERTISE:

Stuart has extensive experience in leading strategic research and development programs in both government and commercial organisations, having held senior management positions in the private and public sectors. His past roles have included technical development roles in the manufacturing sector, Chief Operating Officer and Director of Research roles at CRCMining, and the Executive Director of the Grape and Wine Research and Development Corporation.



DR LARRY JORDAN

BSC, MSC, PHD.
RESEARCH DIRECTOR SINCE AUGUST 2015.

EXPERIENCE AND EXPERTISE:

Larry manages the delivery of the Rail Manufacturing CRC's research program to ensure high quality collaborative research is provided to the rail industry. With a background in materials science and experience in research, including electrochemical sensors, fuel cells and materials durability, Larry has worked in building construction, nanotechnology and automotive industries. Larry's past roles include Research Manager at the Advanced Manufacturing CRC and Chief Scientist at General Motors Holden.



SHARON SALPIGHIDIS

B.COM, DIPED, CPA.
FINANCIAL CONTROLLER AND COMPANY SECRETARY SINCE SEPTEMBER 2016.

EXPERIENCE AND EXPERTISE:

Sharon provides strategic and operational management of the Rail Manufacturing CRC's financial activities and ensures the Centre complies with its statutory obligations. Sharon has previously held senior management positions across both listed public companies and fast-growing private start-up enterprises, facilitating multiple mergers, acquisitions and divestments. She has previously worked both locally and overseas in diverse industries including healthcare, construction, education and most recently in telecommunications.



KATIE RIZZO

BARTS, GRADCERT.
COMMUNICATIONS MANAGER
SINCE JUNE 2016.

EXPERIENCE AND EXPERTISE:

Katie is responsible for managing the communications function for the Rail Manufacturing CRC, which includes marketing, media engagement, event management and internal communications activities. Prior to joining the Centre, she worked in corporate communications, marketing and online communications roles across several sectors, including manufacturing, telecommunications, banking, energy and water.



HEIDI KRASULAK

ASSOCIATE DIPLOMA IN ADMINISTRATION, CERT IV BOOKKEEPING.
FINANCE AND RECORDS OFFICER SINCE JANUARY 2019.

EXPERIENCE AND EXPERTISE:

Heidi has extensive experience in business administration, bookkeeping, payroll and records management. Heidi's professional background includes general law including commercial contracts and settlements. Heidi assists with the financial and contract management for the Centre, including reporting and the annual audit process.



PROF COLIN COLE

BENG, MENG, PHD.
PROGRAM LEADER SINCE APRIL 2015.

EXPERIENCE AND EXPERTISE:

Colin is the Director of the Centre for Railway Engineering (CRE) and also currently serves as a Program Leader in the Rail Manufacturing CRC. He's spent the past 25 years working specifically in railway research, completing more than 20 rail research projects related to train dynamics, simulation and development of on-board intelligent systems and devices. He has published over 100 technical papers, one book, two book chapters and two patents.



PROF PAUL MEEHAN

BENG(HON1), PHD.
PROGRAM LEADER SINCE MARCH 2017.

EXPERIENCE AND EXPERTISE:

Paul is an expert in railway mechanics and noise, leading the University of Queensland research in rail mechanics as part of the Centre for Advanced Materials Performance and Manufacturing (AMPAM). He has led many successful large industry collaborative R&D projects totaling more than \$12 million in competitive research funding. He also teaches several intermediate and advanced level courses in mechanics. He has authored over 120 internationally refereed publications and three international patents.

Name*	Organisation	Position title	Time committed
Stuart Thomson	Rail Manufacturing CRC	Managing Director and CEO	100%
Larry Jordan	Rail Manufacturing CRC	Research Director	100%
Heidi Krasulak	Rail Manufacturing CRC	Finance and Records Officer	80%
Sharon Salpighidis	Rail Manufacturing CRC	Financial Controller and Company Secretary	60%
Katie Rizzo	Rail Manufacturing CRC	Communications Manager	60%
Colin Cole	Rail Manufacturing CRC / CQUniversity	Program Leader	51%
Paul Meehan	Rail Manufacturing CRC / University of Queensland	Program Leader	51%

*One additional employee during this time period was Mitali Pandit as Finance and Records Officer (working from November 2017 to November 2018).

Participants

BOMBARDIER



Essential Participants

Participant name	Participant type	ABN	Organisation type
Bombardier Transportation Australia Pty Ltd	Essential	73 010 699 804	Large Industry
Central Queensland University	Essential	39 181 103 288	University
China Railway Rolling Stock Corporation (CRRC)	Essential	Not applicable	Large Industry
CSIRO	Essential	41 687 119 230	Australian Government
Deakin University	Essential	56 721 584 203	University
Downer EDI Rail Pty Ltd	Essential	92 000 002 031	Large Industry
Monash University	Essential	12 377 614 012	University
OneSteel Manufacturing Pty Ltd **	Essential	42 004 651 325	Large Industry
Queensland University of Technology	Essential	83 791 724 622	University
Swinburne University of Technology	Essential	13 628 586 699	University
The University of Queensland	Essential	63 942 912 684	University
University of Technology Sydney	Essential	77 257 686 961	University
University of Wollongong	Essential	61 060 567 686	University

Other Participants

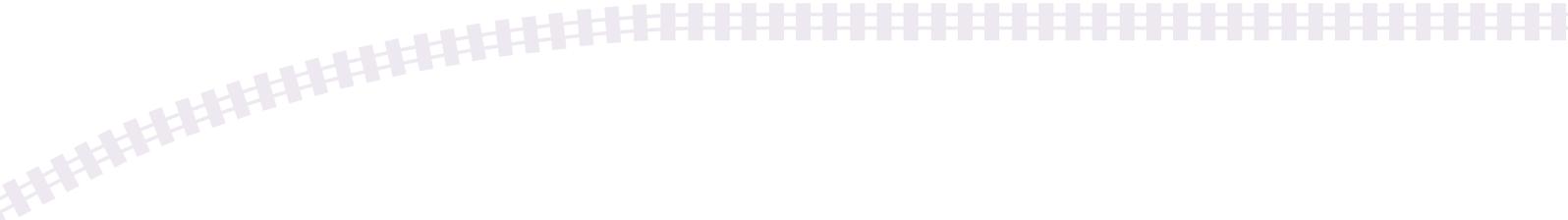
Participant name	Participant type	ABN	Organisation type
Airlinx Heating and Cooling Pty Ltd	Other	28 094 691 791	Individual SME
Australasian Centre for Rail Innovation (ACRI) Ltd	Other	52 164 764 167	Other
Australasian Railway Association	Other	64 217 302 489	Other
Department of Transport (Victoria) *	Other	69 981 208 782	State Government
Foundation QA	Other	78 090 519 289	Individual SME
Global Synthetics	Other	71 120 519 520	Individual SME
HEC Group	Other	18 165 129 260	Large Industry
Knorr-Bremse Australia Pty Ltd	Other	31 092 562 671	Large Industry
Royal Melbourne Institute of Technology	Other	49 781 030 034	University
Sydney Trains	Other	38 284 779 682	State Government
TrackSAFE Foundation	Other	98 155 604 872	Individual SME
Tyre Stewardship Australia Ltd	Other	44 164 971 939	Individual SME
UGL Rail Services Pty Ltd	Other	58 000 003 136	Large Industry
Victoria University *	Other	83 776 954 731	University

Third Party Participants

Participant name	Participant type	ABN	Organisation type
Austrade	Third Party	11 764 698 227	Government
Queensland Rail Ltd	Third Party	71 132 181 090	Large Industry

* During this Financial Year, two new organisations joined as Other Participants – the Department of Transport (Victoria) and Victoria University.

** As per the original terms and conditions of its Participants Agreement, OneSteel will cease to be an Essential Participant as of December 2019.



Collaboration

During 2018–19, the Rail Manufacturing CRC has continued to promote and participate in several initiatives aimed at growing engagement between its Participants cohort and other organisations.

Through direct involvement with Participants, the Rail Manufacturing CRC has been able to foster links between its postgraduate cohort and its Industry Participants. Several of the Centre's Industry Participants and third party organisations are currently providing support to the PhD students through access to expertise, data, materials and general information, all of which strengthens the quality of research work delivered by the students.

The Rail Manufacturing CRC's current suite of projects are providing considerable benefit to its Participants, with 25 projects underway during 2018–19, ten projects completed and 30 PhD scholarships underway.

The Rail Manufacturing CRC's participation in numerous rail industry forums has enabled the Centre to develop relationships with worldwide rail manufacturers, rail operators and Government organisations. The Centre has participated in several joint industry briefings, conferences, forums and peak body advisory groups, and continues to work closely with rail peak bodies including the Rail Industry Safety and Standards Board (RISSB) and the Australasian Railway Association (ARA).

In September 2018, the Rail Manufacturing CRC participated in the Australian delegation to InnoTrans in Germany. Sponsored by Austrade, the New South Wales and Victorian State Governments, and the ARA, the delegation was supported by 41 companies and 100 Participants. The trip provided a multitude of opportunities for the Rail Manufacturing CRC to engage with government, industry and research representatives and to view the latest advances in rail technology from over 3,000 Innotrans exhibitors.

The Centre also participated and promoted rail innovation at a number of key forums, including the Metro Rail Stations and Terminals Summit 2019, Inland Rail Summit 2019, the Transport 2056 Executive Round Table organised by Engineers Australia, AusRAIL 2018, ARA's Rail Industry Group meetings, State Government forums, collaborative Smart Rail Map workshops with the ARA and Deakin University, the CRC Association annual conference, the Rail Manufacturing CRC's Participant Forums, and other academic and industry forums.



Australian contingent at InnoTrans 2018 in Berlin, Germany

Collaborative projects with commercial potential

A number of the Rail Manufacturing CRC's current projects are providing considerable benefit to their Participants, with several project examples having commercial potential:

» Project R1.1.1 - **New generation lithium-ion batteries with high energy and long service life for rail industry application** (HEC Group / University of Technology Sydney)

Project R1.1.2 - **Hybrid supercapacitors with high energy and power densities for rail industry applications** (HEC Group / University of Technology Sydney):

These two projects by HEC Group and the University of Technology Sydney seek to develop new battery and supercapacitor technologies for rail. Developing better battery materials have far-reaching applications in rail, with the potential for use in the development of hybrid trains.

» Project R1.3.4 - **Supercapacitor energy management system stage 2** (CRRC / CSIRO):

Energy storage control systems being developed jointly by CRRC and CSIRO hold significant opportunities for the domestic and global rail sector. This work has involved the prototyping of an energy management system currently being tested by CRRC in China.

» Project R2.3.2 - **Axle bearing maintenance optimisation** (Bombardier / University of Queensland)

This recently completed project has the potential to reduce maintenance and overhaul requirements for rolling stock by examining methods to model and predict lubrication needs for the maintenance of the axle bearings, in turn resulting in reduced operational costs.

» Project R3.1.2 - **Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system** (Downer / University of Technology Sydney):

This project developed Dwell Track™, a passenger tracking technology that is being trialled in the Sydney Trains network, starting in August 2019. Sixteen cameras have been installed at Wynyard station to use algorithms that 'sense' crowd movement. The data will provide staff with information to help reduce platform congestion and direct passengers more efficiently and effectively, while also providing long term insights into platform operations around dwell management.

» Project R2.1.2 - **Protection of cast steel coupler from corrosion by cold spray** (CRRC / CSIRO):

Cold spray is a metal coating technology that uses a supersonic jet to accelerate particles towards a substrate so that they deform and bond. A chief advantage of cold spray is that it does not use a large amount of heat, which would otherwise alter the substrate microstructure. Since metallic bonds form between particles, cold spray coatings exhibit high strength and adhesion compared with mechanical plating methods. Following successful demonstration of the technology, it is likely that CRRC will implement the use of cold spray in its manufacturing facilities.

» Project R3.6.1 - **Experimental and computational study on the key ventilation issues affecting air quality and thermal comfort in train cabins** (Airlinx / RMIT University):

This project has developed a 3D model to predict thermal airflow and contaminant dispersion in train cabins. The project outputs have been used to design ventilation systems for passenger train cabins, but also have applicability for other industry uses such as commercial buildings.

Financial management

For the year ended 30 June 2019, the Rail Manufacturing CRC expended its financial resources on:

- » contracting new research projects
- » managing and supporting existing research projects
- » awarding and managing student PhD scholarships
- » developing its pipeline of potential new research projects with both existing and new Participants.

Financial performance

For the year ended 30 June 2019, the Rail Manufacturing CRC earned revenue of \$6.83 million and other income of \$0.21 million, and incurred expenses of \$7.04 million, resulting in a \$nil operating profit. Revenue of \$6.83 million comprised \$4.14 million of CRC Program Funding from the Department of Industry, Innovation and Science and \$2.69 million from Participants. Expenditure of \$7.04 million included \$5.38 million of research costs, \$1.20 million of employee benefits costs and \$0.46 million of administration and depreciation expenses.

Research expenditure has increased by \$1.17M or 28% compared to last year. This result is \$3 million lower than budgeted, due in part to unmet contributions from existing Participants, delays in some existing projects and a number of anticipated projects with potential new Participants which did not eventuate.

Cash flows

During the year, the Rail Manufacturing CRC received \$9.10 million of operating cash inflows (inclusive of GST), consisting of \$5.25 million from the Commonwealth CRC Program, \$3.65 million from Participants and \$0.20 million in interest receipts. Operating cash outflows totalled \$7.50 million (inclusive of GST), consisting of \$5.70 million of research payments and \$1.80 million of administration payments. There were no investing cash flows this year.

In-kind contributions

Total in-kind contributions of \$13.7 million for the year ended 30 June 2019 comprised \$12.5 million of staff in-kind and \$1.2 million of non-staff in-kind contributions, being non-cash contributions to the Rail Manufacturing CRC's research programs by Research and Industry Participants, representing contributions of people, equipment and facilities.

Financial position

As at 30 June 2019, total assets were \$15.8 million and total liabilities were \$15.8 million. Total assets are comprised predominantly of cash and cash equivalents of \$14.5 million, trade and other receivables of \$0.8 million and prepayments of \$0.5 million. Total liabilities are comprised predominantly of deferred revenue of \$11.7 million, trade and other payables of \$3.8 million and provisions of \$0.2 million.

Financial issues

The key financial challenges, for the next, final year, in order to meet the Centre's current obligations to the Commonwealth, are to:

- » managing existing research projects and costs in a timely manner
- » oversee student scholarship funding, extensions and clawback provisions
- » delivering financial outcomes in line with the wind-up plan for the conclusion of the Centre.





Passengers on the Queensland rail network



Sydney Trains network at dusk

CRC future plans and transition arrangements

The Rail Manufacturing CRC began in 2014, with a mandate to operate for six years. The Centre will not be transitioning to an alternate entity, so the Rail Manufacturing CRC will conclude operations at the end of the next Financial Year.

In preparation for closing, the Centre has developed a wind-up plan which is detailed on pages 58-68 of this report. The plan includes activities covering the Centre's employees, students, existing contracts, intellectual property, assets, document archiving and insurance.

As part of the transitioning arrangements, the Centre will be working with its Participants to ensure outcomes from current projects will be utilised internally or alternatively continued through ongoing research activities conducted in future.



Performance review

No performance reviews were conducted in the 2018–19 Financial Year.

Other activities

In 2018–19, the Rail Manufacturing CRC continued to participate in multiple industry forums aimed at progressing collaboration within the rail sector.

These initiatives included:

- » participating in Austrade rail industry forums including the India and Australia Rail Collaboration meetings held in Australia and InnoTrans in Berlin
- » supporting and attending activities recommended by the Advanced Manufacturing Growth Centre
- » participating in several State Government briefings and forums.

The Centre has a memorandum of understanding (MoU) in place with the Advanced Manufacturing Growth Centre and continues to look for synergies with the Growth Centre where applicable.

Overview of wind-up plan

This section provides an abridged outline of the wind-up plan and activities that were provided to the CRC Program in June 2019.

Ceasing operations

In January 2018, the Rail Manufacturing CRC Board met to discuss the future of the Centre, where it was determined that actions should be taken to prepare for the wind-up of its operations in 2020.

On 30 June 2020, the Commonwealth funding Agreement will end. Following the termination of the funding Agreement, the Centre has indicated to the Commonwealth Government that the Rail Manufacturing CRC Ltd will continue to operate until 30 September 2020 to complete all reporting and company wind-up obligations.

At the conclusion of this period, the company will cease operations and its registration as a Not-For-Profit (NFP) registered entity and a company limited by guarantee will cease.

This wind-up plan overview includes the following information:

- » Governance
- » Contact details
- » Activities status
- » Financial management
- » Final year prospective budget
- » Intellectual Property
- » Assets
- » Taxation





Next generation rolling stock from Bombardier on the Queensland Rail network

Governance and management

Participants roles and responsibilities

On 8 April 2019, the Board formally adopted resolutions for the wind-up of the Rail Manufacturing CRC and approved the subsequent resolutions to be put to the Centre's Members and Essential Participants. The resolutions contained an outline of the obligations each Participant was required to approve to ensure the Centre could wind-up in June 2020. Following the circulation of the respective Member and the Essential Participant resolutions, the required 75 per cent approvals for both resolutions were obtained.

Meetings were scheduled with the Project Leaders/Supervisors of all active projects and scholarships in May to July 2019 to discuss obligations and expectations relating to individual projects and to outline wind-up activities.

These meetings have been followed with regular formal communications from the Centre to the Participants to remind them of their obligations and to address any issues relating to individual projects in the coming 12 months.

Management resourcing to complete all Centre obligations

During the period from 1 July to 30 September 2020, the Board will retain, at a minimum, two independent Non-executive Directors and a third Director chosen from the Centre's management to oversee the Rail Manufacturing CRC through this wind-up period.

The required staff will be retained as required to ensure the Centre completes all obligations to the Commonwealth Government under the guidelines and Funding Agreement. Provision has been made for all staff entitlements and appropriate actions taken to retain staff as needed.

Transition of human resources

The Rail Manufacturing CRC directly employs five staff at its offices in North Melbourne and two academic Program Leaders based at CQUniversity and the University of Queensland respectively. All staff are contracted under a fixed term employment agreement, and where required, casual staff are also utilised. These employment agreements will end as required. Centre Head Office staff will then be able to seek alternative employment, while the Program Leaders will continue to work for their respective universities.

For Research Participant staff participating in the Centre's projects, their contractual arrangements will be a matter for the individual research organisations who employ those staff.

For postgraduate students co-sponsored through the Centre's programs, arrangements will be made to ensure funding is provided to their respective universities so that the students can complete their studies as outlined in their individual student agreements. Prior to the closure of the Centre, all arrangements and funding commitments will be met by the Rail Manufacturing CRC to the respective universities, and provision has been made for all student entitlements.

Storage and archiving of documentation

Post 30 September 2020, storage of the Centre's documentation and copies of data files and relevant hardware and online content will be retained for a period of seven years.

Prior to 30 June 2020, the Rail Manufacturing CRC will write to all Participants reinforcing their obligations to retain records as required by the Commonwealth Agreement and the Participants Agreement for a period of at least seven years.

Return of Commonwealth Confidential Information

The Centre and its Essential Participants are required, at the request of the Commonwealth or the Rail Manufacturing CRC, to promptly return all physical and written records, and documentation (including copies) containing Commonwealth Confidential Information in a form reasonably requested.

Alternatively, if requested by the Commonwealth, the Essential Participants must destroy such items as the manner specified and promptly certify in writing that it has done so.

During the first quarter of the 2020 calendar year, the Centre will seek confirmation from the Commonwealth with regards to its Confidential Information, if any, that it wishes to be returned or destroyed. Subsequently, the Centre's Participants will be notified and reminded of their obligations.

Ceasing use of CRC Branding

The term of the non-exclusive sub-licence granted by the Commonwealth to the Rail Manufacturing CRC and subsequently to the Essential Participants to use the CRC Branding comes to end at 30 June 2020, unless otherwise agreed to, in writing by the Centre.

Prior to 30 June 2020, Essential Participants will be reminded of their obligations to cease use of any CRC Branding or advise of alternate arrangements should they exist.

Related Incorporated entities

The Rail Manufacturing CRC does not control any incorporated entities, and the Centre's IP model precludes any requirements for the creation of an IP holding entity.

Contact details

The Rail Manufacturing CRC's CEO Dr Stuart Thomson will be responsible for managing the ceasing operations process and can be available post 30 September 2020 as a contact point to assist with any outstanding reporting requirements or information requests.

Activities status

The Rail Manufacturing CRC seeks to leave the rail manufacturing sector with a legacy that ensures relationships built between industry and research providers will continue to prosper following the Centre's closure. This is supported by a renewed industry enthusiasm regarding the importance of innovation and the value that research collaborations provide.

Research

The Rail Manufacturing CRC's key goal is to deliver the research outputs described in the Funding Agreement with the Commonwealth Government by 30 June 2020. With a wide range of projects that are addressing most of the milestones, it is anticipated that the Centre will achieve the majority of its Commonwealth milestone obligations.

When funding concludes, the Rail Manufacturing CRC will have played a key role in fostering a greater R&D culture within the Centre's Industry Participants and the broader Australian rail manufacturing sector. It is hoped that the rail sector continues to maintain collaborations with publicly-funded research organisations to deliver innovative industry-leading projects moving forward.

Status of milestones and outputs

The following table outlines the Rail Manufacturing CRC's expected status against activities outlined in the Funding Agreement upon Centre wind-up, including those activities completed, terminated, continued or transferred:

Outputs yet to be completed / Milestones yet to be achieved	Expected Status at end of agreement period (completed / terminated / transferred)	If transferred, organisation(s) responsible for ongoing activities after the agreement period
Program 1 – Power and Propulsion		
R1.1.4, U1.1.2, U1.1.3	Completed	
R1.2.1, R1.2.2	Terminated ⁷	
R1.3.6, R1.3.7, U1.3.3, U1.3.4, U1.3.5	Completed	
U1.4.2, U1.4.3, U1.4.4	Completed	
R1.4.5, R1.4.6, R1.4.7	Completed	
R1.5.4, R1.5.6	Completed	
R1.5.5	Transferred	To relevant universities
Program 2 – Materials and Manufacturing		
U2.1.6	Completed	
R2.2.4, R2.2.5, R2.2.6, R2.2.7, U2.2.5	Completed	
R2.3.6, R2.3.7, U2.3.5	Completed	
U2.4.5	Completed	
R2.5.5, R2.5.7	Completed	
R2.5.6	Transferred	To relevant universities
Program 3 – Design, Modelling and Simulation		
R3.1.7, U3.1.5	Completed	
U3.2.5	Completed	
U3.3.3, U3.3.4, U3.3.5	Completed	
R3.4.4, R3.4.5, R3.4.6, R3.4.7, U3.4.5	Completed	
R3.5.5, R3.5.6, R3.5.7, U3.5.2, U3.5.3, U3.5.4, U3.5.5	Completed	
R3.6.7, U3.6.4, U3.6.5	Completed	
R3.7.5, R3.7.7	Completed	
R3.7.6	Transferred	To relevant universities

⁷ Related to Industry Participant Simplex who was expelled from the Centre in December 2017

Overview of wind-up plan, continued.

Status of CRC students

The following table summarises the status of student PhD activities, including the current expected timeframe for completion – (as yet, expected completion date does not include any approved six-month extensions scheduled to be granted by the Rail Manufacturing CRC in late 2019).

Student name	Degree type	Expected completion date	Enrolling / Participant organisation
Program 1 – Power and Propulsion			
Tianyi Wang	PhD	August 2021	University of Technology Sydney
Shuoqing Zhao	PhD	August 2021	University of Technology Sydney
Pauline Jaumaux	PhD	August 2022	University of Technology Sydney
Xiaochun Gao	PhD	February 2020	University of Technology Sydney
Yi Chen	PhD	February 2020	University of Technology Sydney
Zhang Yin (Yin)	PhD	January 2020	Queensland University of Technology
Sundar Shrestha	PhD	July 2021	CQUniversity
Esteban Bernal Arango	PhD	July 2021	CQUniversity
Minoo Oveisi	PhD	October 2022	RMIT University
Program 2 – Materials and Manufacturing			
Cameron Milne	PhD	Withdrew – was due to complete January 2018	University of Queensland
Matthew Pozzebon	PhD	October 2019	University of Queensland
Abdul Mannan (Mannan)	PhD	July 2022	University of Queensland
Osama Brinji	PhD	July 2020	University of Queensland
Vijayaragavan Raju (Vijay)	PhD	June 2022	University of Queensland
Chamindi Jayasuriya	PhD	Completed – March 2020	University of Wollongong
Chuhao Liu	PhD	October 2020	University of Wollongong
Mahsa Taherimandarjani	PhD	April 2022	Swinburne University
Meng Wang	PhD	January 2022	Swinburne University
Fukun Xia	PhD	December 2021	Swinburne University
Vu Trong Thien (Terence)	PhD	August 2020	University of Wollongong
Hang Su	PhD	September 2020	Monash University
Pravin Urudra	PhD	Withdrew – was due to complete March 2020	Monash University
Simon Wagner	PhD	May 2022	CQUniversity
Elias Salloum	PhD	February 2022	RMIT University
Mohammad Adinehvand	PhD	November 2022	RMIT University
Anthony Micheletto	PhD	April 2021	Monash University
Tommy Huynh	PhD	December 2022	RMIT University
Panahsadat Fasihi	PhD	November 2021	Monash University
Don Kushlani Ranmal Ranasinghe	PhD	Withdrew – was due to complete June 2019	Queensland University of Technology
Zheshuo Zhang	PhD	Completed – April 2019	Queensland University of Technology

Student name	Degree type	Expected completion date	Enrolling / Participant organisation
Program 3 – Design, Modelling and Simulation			
Alexander Virgona	PhD	October 2019	University of Technology Sydney
Julien Collart	PhD	January 2020	University of Technology Sydney
Mahdi Saki	PhD	September 2023	University of Technology Sydney
Zhibin Li	PhD	March 2021	University of Technology Sydney
Huaxi Huang	PhD	April 2022	University of Technology Sydney
Amir Eslami	PhD	Reverted to Masters – was due to complete PhD in September 2020	Monash University
Yufung Lee (Joseph)	PhD	June 2020	Monash University
Chi Hei Vong (Calvin)	PhD	July 2020	Monash University
Yong Pang	PhD	August 2020	Monash University
Dongyu Zhang	PhD	October 2020	Monash University
Nalin Randeniya	PhD	June 2021	Swinburne University
Andrew Danylec	PhD	June 2021	Swinburne University
Wenhua Jiang	PhD	January 2021	Monash University
Don Skerman	PhD	October 2022	CQUniversity
Jie Yang (Joanne)	PhD	June 2022	RMIT University
Bibek Baral	PhD	October 2021	University of Wollongong
Peter Allen	PhD	August 2021	Swinburne University
Alejandro Tamani	PhD	November 2022	RMIT University

Financial management and budget provisions

During the last 18 months, the Rail Manufacturing CRC has developed a significant pipeline of project proposals which have resulted in several new projects for the Centre. A high proportion of these new projects are likely to provide commercial outcomes for Participants.

In assessing the Centre's financial commitments, the Rail Manufacturing CRC Management team has put strategies in place to ensure the Centre closes in the required timeframe. In terms of research projects, the Rail Manufacturing CRC has and will:

1. identify projects with commitments extending into the Financial Year ending 30 June 2020
2. identify any key projects that are of importance in terms of possible future industry funding and/or commercialisation
3. in consultation with Industry Participants, identify any projects that may enter a new phase of research (ie. continue after 30 June 2020 on the basis they will be new endeavours funded entirely by Participants or other parties) that will be transferred to a Participant research provider if continuing past 30 June 2020 (see 5)
4. in consultation with Research Participants, identify those projects (or Programs) that the research provider would like to absorb and if required, arrange an orderly transfer of staff, contractual obligations, IP and know-how to that university by 30 June 2020
5. plan to complete all current projects by 30 June 2020.

Across 2018–19, the Rail Manufacturing CRC has been in discussions with numerous parties with respect to undertaking new projects. Due to the Centre's remaining lifetime, some of these project proposals are unable to be funded. The Rail Manufacturing CRC will continue to promote R&D collaboration during its final year and, where possible, provide introductions for industry partners to other funding organisations.

Financial considerations for existing contracts

As part of the Centre's wind-up strategy, staff are monitoring all R&D related agreements and acting to ensure that commitments, financial or otherwise, do not run past 30 June 2020.

Financial considerations for Directors and staff

The Centre has identified those directors, administration and technical staff that will be required to run the Centre through to 30 June 2020, in addition to those individuals who will deal with legacy issues post this date. Currently, full provision is made for all employee and Board entitlements out to 30 September 2020.

Legal costs

The Board has considered the question of legal costs and provision has been made for possible contingencies.

Financial considerations for students

In terms of the Centre's commitments to its postgraduate students, the Rail Manufacturing CRC will identify and quantify the financial commitment to its students through to June 2020 and beyond to ensure provisions are made to cover all future payments to the relevant universities for the students' minimum term of three years.

Acquittal of Commonwealth Funds

The Rail Manufacturing CRC will regularly report on its expenditure through to 30 June 2020, with the Centre to continue engaging with the Department of Industry, Innovation and Science through 2019–20. Unspent Commonwealth Funds will be returned to the Commonwealth Government, and unspent Participant funds will be returned to the respective Participant organisations.

Expected allocation of any remaining Commonwealth Funds

As the Rail Manufacturing CRC will be closing in June 2020, there are no plans to expend residual CRC funds. Any unallocated Commonwealth funds will be returned.

Completion of independent audit

Arrangements for the Rail Manufacturing CRC's final audit for 2019–20 have been determined by the Board in consultation with the Centre's auditors, where post 30 June 2020, an audit will be undertaken. A final review of the Centre's financial records will also be undertaken by the Centre's auditors for the period of 1 July to 30 September 2020, with a report to be provided to the Board.

Overview of wind-up plan, continued.

Final year prospective budget

The Rail Manufacturing CRC's progress in securing projects during 2014 to 2016 was slow due to several external sector-wide factors previously been reported in past Annual Reports – for more detail, see the Chair/MD letter on pages 4–5.

Nonetheless, the Centre has continued to be proactive in promoting its activities and has continued to initiate innovative projects that seek to realise value for the Centre's Participants.

The final year prospective budget has been provided to the CRC Program in June 2019 and is available upon request.

Management of Intellectual Property

The Rail Manufacturing CRC's IP arrangements, as set out in the Centre's Participant Agreement and the individual Project Agreements, ensure that IP created during a project is assigned to the relevant Industry Participant(s) and/or the R&D Participant(s).

The Rail Manufacturing CRC does not hold, nor has a commercial interest in, IP relating to research projects and therefore, no IP holding entity arrangements post 30 June 2020 will be required for project-related IP. The commercial use or publication of research-related IP has been defined in the respective Project Agreements. Ownership and terms of use are similarly defined.

For non-commercial IP created through the Centre's funded research activities, Research Participants will be responsible for the publication of research findings.

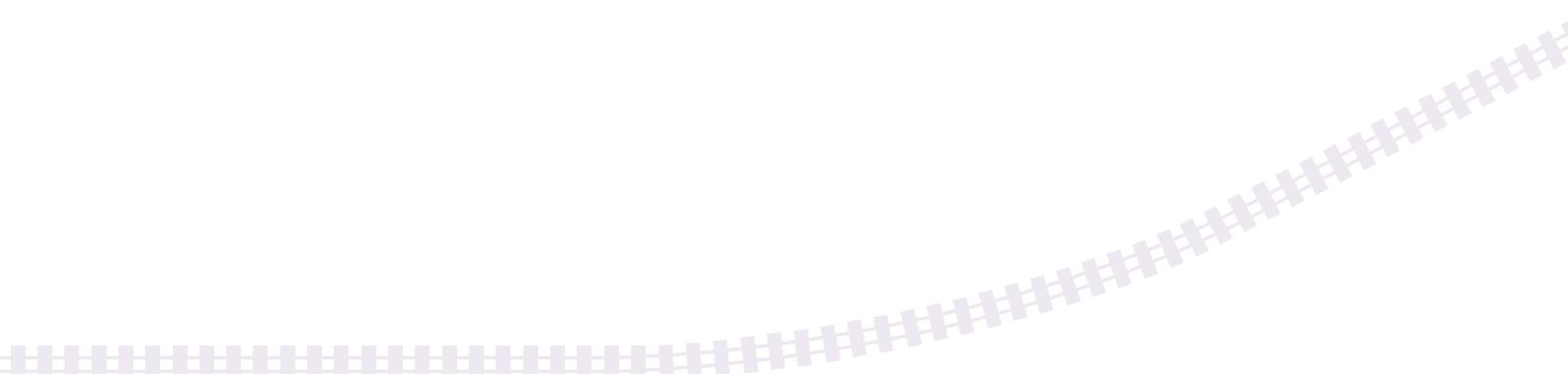
Assets

The Rail Manufacturing CRC has not directly purchased, nor owns, any capital item (defined as items above \$50,000).

Taxation

The Rail Manufacturing CRC has been endorsed for charity tax concessions by the Australian Taxation Office (ATO) under Division 50 of the Income Tax Assessment Act 1997, with effect from June 21 2014, which includes exemption from income tax. Employee related taxes including payroll tax and PAYG will be accrued to the end of the employment period. GST will be accrued and paid to the end of the cash transaction period.

The Centre will seek to ensure it meets all taxation obligations prior to its closure.



Exit report

The Rail Manufacturing CRC will wind-up on 30 June 2020 at the end of its six-year Commonwealth funding period. In the final months of operation, the Centre will work with its Research and Industry Participants to ensure the successful completion of activities.

During its lifespan, the Rail Manufacturing CRC has delivered new technologies and knowledge to the sector, and built an awareness about the importance of R&D in the Australian rail manufacturing environment.

By fostering strong working relationships between Industry Participants and publicly-funded research agencies, it is hoped that these partnerships, nurtured by the Rail Manufacturing CRC since commencement, will serve the sector for many years to come.

This exit report summarises the Rail Manufacturing CRC's impact to date. This report will be updated and finalised in the Centre's last Annual Report for the 2019–20 Financial Year.

Direct economic benefits achieved

Since establishing in 2014, the Rail Manufacturing CRC has worked consistently to identify project opportunities that have the potential to provide tangible benefits to the rail industry. This has resulted in the development of the following four products to-date:

Dwell Track™

Licensed by Downer and patented by the University of Technology Sydney, Dwell Track™ uses 3D imaging cameras, algorithms and software to track passenger numbers and movement at station platforms. The core application of Dwell Track™ is to reduce the length of time it takes passengers to embark and disembark from a train, optimising passenger flow through monitoring and automated actions. With a trial now underway with rail operator Sydney Trains, data collected will be used to further build upon the technology developed. Following this major trial, the aim is for Dwell Track™ to be commercially available to assist rail operators to improve platform management procedures, reduce train dwell times and potentially increase the capacity of their train services – see case study on page 72.

Smart Rail Route Map

Working with the Australasian Railway Association and Deakin University, this technology road map provides priorities to the rail industry for developing initiatives and programs for the integration of the next-generation of digital and telecommunications technologies. Following the release of the Smart Rail Route Map, a Smart Rail Executive Committee has been formed comprising of key representatives from the rail sector to develop strategies for implementing the priorities.

Axle bearing wear modelling software

The Rail Manufacturing CRC collaborated with Bombardier and the University of Queensland to predict the wear rates of axle bearings used in suburban passenger trains. The software model predicts bearing life through algorithms developed for lubrication and bearing wear. This enables Bombardier to optimise the bearing selection, lubrication and overhaul maintenance schedule with significant economic benefits due to bearing life management and integration with other overhaul activities – see case study on page 73.

Arc welding modelling software for rail

This project was partnership with CSIRO and CRRC to develop a user-friendly computer program to predict the properties of rail component welds. The software allows accurate prediction of the heat transfer to the welded metal for a wide range of parameters, which is expected to greatly reduce the number of experimental tests required in developing weld designs for rolling stock fabrication. The implementation of the software produced will result in large savings in staff time and result in significant productivity improvements. Moreover, optimised weld parameters can save expenditure on consumables such as shielding gases, while also providing assurance to the high quality of the weld.



Dwell Track™ technology on display highlighting passenger movement on and off the train

CASE STUDY

Understanding passenger congestion

Efficient movement of passengers across a network is at the core of any transport network. Central to this is reducing dwell time, the total period the train remains stationary at the platform for door operations and passenger motion (embarking and disembarking).

In early 2015, the Rail Manufacturing CRC partnered with the University of Technology Sydney and Downer on Project R3.1.2 - **Integrated passenger behaviour, train operations diagnostics and vehicle condition monitoring system** to fund the development of Dwell Track™, a tool capable of detecting key dwell events relating to train and passenger movements in crowded environments.

Using spatial data, Dwell Track™ leverages advances in 3D camera technology combined with algorithms to identify passenger movement and numbers in a crowd.

Dwell Track™ determines train door positions, door status, passenger counts and the direction passengers are moving, all of which supports the more efficient management of passengers. The technology also provides rail operators with the capability to generate and analyse data to influence passenger behaviour in real-time, while also further developing and testing strategies for long-term dwell time management.



CASE STUDY

Axle bearing wear

For operators and maintainers, effectively balancing maintenance requirements with operational availability and cost is an important aspect of asset management. Understanding bearing durability through informed bearing and lubricant selection, life prediction and maintenance practices can have considerable impact on operational performance.

Commencing in 2015, Bombardier and the University of Queensland started work on Project 2.3.2 - **Axle-bearing maintenance optimisation** to investigate the wear and degradation of the axle bearings used in a suburban fleet for passenger transport, with an aim to predict the wear and optimise the lifespan of the bearings.

In this project, a model and tool were created to predict bearing wear by selecting lubricant and operational parameters, with a goal to extend the life of bearings performing well below their fatigue threshold.

Due to the collaboration between academic researchers and the rail industry, facilitated by the Rail Manufacturing CRC, this work provided a validated predictive model to optimise axle bearing maintenance over rolling stock fleet lifetime.

The impact of collaboration

Participant organisations

The Rail Manufacturing CRC has had 35 Participant Organisations involved in its operations since commencing in 2014, including 16 Essential Participants, 14 Other Participants and five Third Party Participants:

#	Organisation	Participant type	ABN	Organisation type	Period of Participation
1	Bombardier Transportation Australia Pty Ltd	Essential	73 010 699 804	Large Industry	2014 to current
2	Central Queensland University	Essential	39 181 103 288	University	2014 to current
3	China Railway Rolling Stock Corporation (CRRC)	Essential	Not applicable	Large Industry	2014 to current
4	CSIRO	Essential	41 687 119 230	Australian Government	2014 to current
5	Deakin University	Essential	56 721 584 203	University	2014 to current
6	Downer EDI Rail Pty Ltd	Essential	92 000 002 031	Large Industry	2014 to current
7	Faiveley Transport Australia	Essential	41 000 611 898	Large Industry	2014 to 2017
8	Monash University	Essential	12 377 614 012	University	2014 to current
9	OneSteel Manufacturing Pty Ltd	Essential	42 004 651 325	Large Industry	2014 to current
10	Queensland University of Technology	Essential	83 791 724 622	University	2014 to current
11	Sigma Air Conditioning Pty Ltd	Essential	31 000 900 970	Individual SME	2014 to 2018
12	Simplex Factory Automation Pty Ltd	Essential	81 094 159 896	Individual SME	2014 to 2017
13	Swinburne University of Technology	Essential	13 628 586 699	University	2014 to current
14	The University of Queensland	Essential	63 942 912 684	University	2014 to current
15	University of Technology Sydney	Essential	77 257 686 961	University	2014 to current
16	University of Wollongong	Essential	61 060 567 686	University	2014 to current
17	Australasian Centre for Rail Innovation (ACRI) Ltd	Other	52 164 764 167	Other	2015 to current
18	Australasian Railway Association	Other	64 217 302 489	Other	2014 to current
19	Airlinx Heating and Cooling Pty Ltd	Other	28 094 691 791	Individual SME	2015 to current
20	Department of Transport (Victoria)	Other	69 981 208 782	State Government	2019 to current
21	Foundation QA	Other	78 090 519 289	Individual SME	2017 to current
22	Global Synthetics	Other	71 120 519 520	Individual SME	2017 to current
23	HEC Group	Other	18 165 129 260	Large Industry	2017 to current
24	Knorr-Bremse Australia Pty Ltd	Other	31 092 562 671	Large Industry	2017 to current
25	Royal Melbourne Institute of Technology	Other	49 781 030 034	University	2015 to current
26	Sydney Trains	Other	38 284 779 682	State Government	2017 to current
27	TrackSAFE Foundation	Other	98 155 604 872	Individual SME	2016 to current
28	Tyre Stewardship Australia Ltd	Other	44 164 971 939	Individual SME	2016 to current

#	Organisation	Participant type	ABN	Organisation type	Period of Participation
29	UGL Rail Services Pty Ltd	Other	58 000 003 136	Large Industry	2016 to current
30	Victoria University	Other	83 776 954 731	University	2019 to current
31	Aurizon Network Pty Ltd	Third Party	78 132 181 116	Large Industry	2016 to 2018
32	Austrade	Third Party	11 764 698 227	Government	2014 to current
33	Industry Capability Network Ltd	Third Party	85 068 571 513	Government	2014 to 2016
34	Queensland Rail Ltd	Third Party	71 132 181 090	Large Industry	2014 to current
35	The State of Queensland (Department of Transport and Main Roads)	Third Party	39 407 690 291	State Government	2016 to 2018

Publications reported

Since commencing in 2014–15, Rail Manufacturing CRC Researchers and PhD Students have reported their research through 59 publications, which includes:

- » 2 book chapters
- » 25 peer-reviewed papers published in scientific journals
- » 32 peer-reviewed conference proceedings.

Number of book chapters

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Media table

The Rail Manufacturing CRC has achieved the following media coverage:

Date	Media outlet	Title
August/September 2019	AMT Magazine	Top industry award for Australian rail innovation
August 7, 2019	railway-news.com	New Infrared Technology to Reduce Dwell Times in Sydney
August 6, 2019	CIO Australia	Sydney Trains commences Dwell Track™ trial to ease crowding, reduce delays
May 20, 2019	Manufacturers' Monthly	Swinburne origami-inspired materials to strengthen trains
April/May 2019	AMT Magazine	One-on-one with Stuart Thomson
December 18, 2018	Manufacturers' Monthly	Sydney Trains executive joins Rail Manufacturing CRC Board
December 10, 2018	Infrastructure Magazine	Closing the gap for train passengers
December 4, 2018	Global Railway Review	Mind the gap project aims to improve passenger access and safety
November 28, 2018	Rail Express	ARA Smart Rail Route Map report released
November 2018	Rail Express Magazine	Harnessing processing power to develop smarter train assembly
September 2018	Infrastructure Magazine	The energy technology that could overhaul tram systems
August/September 2018	AMT Magazine	Work commences on Australia rail technology map
July 27, 2018	Manufacturers' Monthly	Behind the scenes at CSIRO
July 16, 2018	Australian Manufacturing	Developing a Smart Rail Route Map for Australia's rail industry
July 13, 2018	Rail Express	Collaborative research to map route for rail technology development
July 12, 2018	railway-news.com	Australian Railway Association Working With Academics on 'Smart Rail Route Map'
July 12, 2018	Railway Technology	Rail technology map project launches in Australia
July 12, 2018	Infrastructure Magazine	Smart rail route map under development
July 11, 2018	Global Railway Review	The project to establish an Australian rail technology map progresses
July 11, 2018	Railway Pro	Australian rail technology map to be developed
June 18, 2018	CSIROscope	Supercapacitor magic, making tram power lines *disappear*
June 18, 2018	Manufacturers' Monthly	Prototyped CSIRO energy management system to power rail delivered to China
May-June 2018	Rail Express	Developing supercapacitors to power rail rolling stock
May 29, 2018	University of Wollongong	Engineering student wins national Early Researchers Showcase Competition
May 25, 2018	Computerworld	How Kinect tech and two watermelons could make Australia's trains run on time
May 4, 2018	Manufacturers' Monthly	Hybrid supercapacitors to power rail rolling stock
April/May 2018	AMT Magazine	Fostering innovation in rail
November 2017	Rail Express Magazine – Issue 2	Rail Manufacturing CRC on the hunt for final round of projects
October 12, 2017	University of Technology Sydney website	The exciting future of customer experience innovation
March 2, 2017	Manufacturers' Monthly	HEC Group joins Rail CRC to put battery project on-track
December 2016/January 2017	AMT Magazine	Up to \$1m available for rail R&D projects
October/November 2016	AMT Magazine	Time for Australian rail manufacturers to get innovative
October 3, 2016	Sydney Radio 2ser's Think Digital program	It's not just big data, but new data too
July 23, 2015	Government News	Rail gets a manufacturing CRC
February 24, 2014	Manufacturers' Monthly	New Rail Manufacturing CRC successful in latest funding round



Engaging with the Advanced Manufacturing Growth Centre

During its lifetime, the Rail Manufacturing CRC has been proactive in engaging with the Advanced Manufacturing Growth Centre (AMGC), a Commonwealth Government-backed initiative aimed at coordinating industry-led approaches to drive innovation, productivity and competitiveness, highlighting the value that research and education brings to the industry.

A memorandum of understanding was executed with the AMGC, and the two parties meet periodically to collaboratively share information and assist with co-engagement of the two organisations' collective industry networks.

Value statements from Rail Manufacturing CRC Industry Participants

“RMCRC has opened up multiple new opportunities for Airlinx to explore different Industries which have HVAC (heating, ventilation and airconditioning) demand. Throughout our project, the research has been monitored, and the milestones have been checked and reported. We know our investment in R&D has been professionally handled, and all of these events have helped Airlinx to progress and understand the trends of manufacturing, what data is useful and what is not. With the forum and conference meetings, RMCRC has enabled us to focus on our company’s bigger picture, which made decision making simpler.”

Joanne Xia, Accountant – Airlinx



“Our work with the RMCRC has connected Downer with highly capable experts in academia, helping us build long-term collaborative partnerships to solve complex problems in the rail industry. From increased efficiencies in maintenance with data analytics platform TrainDNA, to improving the customer experience by mapping dwell time at stations, the solutions developed through the RMCRC have resulted in real, tangible benefits to our business.”

Tim Young, Executive General Manager
Rolling Stock Services – Downer



“Identifying suitable partners, developing and funding R&D can be a difficult task for companies, in particular for those without dedicated local functions to do this. The Rail Manufacturing CRC has been a success for Knorr-Bremse by helping connect us to appropriate research partners and supporting us to ensure projects are successfully completed. We have undertaken four projects that have added real value to our business, ranging from feasibility studies for new product concepts to product testing regimes, and new and innovative product development.”

Michael McLellan, Managing Director
– Knorr-Bremse Australia



“The HEC Group is a multinational company, and we’re working with the Rail Manufacturing CRC on our first two R&D projects in Australia. From an industry perspective, the most important focus is always identifying those real research outcomes that can be commercialised. With our first fundamental research project to develop lithium batteries, we’ve done nearly two and a half years of a three-year long project. So far, the UTS and HEC research teams have worked very hard together and are now starting to see some commercialisation benefits. I think we’ve got a great relationship with the Rail Manufacturing CRC, who has provided a lot of connection, both with the strategic, overall push for projects, as well as the day-to-day monitoring and support.”

Steven Wan, CEO – HEC Group Australia



The impact of education

Since establishing in 2014–15, the Rail Manufacturing CRC has supported the commencement of 48 students, with two PhD thesis submissions so far.

Number of PhD students

48 students supported through industry projects, scholarships or internships, with:

- » 42 PhDs currently underway
- » The submission of two theses
- » Four students withdrawn

Industry employment

Of the two students who have completed their theses, the Rail Manufacturing CRC is aware that one student has taken a University Research Associate position and the other student is seeking a rail industry position in Australia.

Of the students who withdrew, three are currently employed in manufacturing/engineering positions in Australia.

Student supervision

- » 32 university supervisors from nine universities
- » Mentoring and internship programs run with six industry organisations.

In the past five years, the Centre’s PhD candidates have been diligently working on a wide range of cutting-edge rail research projects, including real-time condition monitoring, using drones for infrastructure assessment, laser cladding technologies, augmented and virtual reality for training, big data analytics and automated assembly of rolling stock fabrication.

With less than one per cent of scientists and researchers working in rail⁸, it is vital to promote the industry as an attractive employment prospect, while also recognising the innovative skills that these highly trained students could bring to Australia’s future rail industry.

To encourage the Centre’s students to consider a career in rail after graduation, a variety of supporting initiatives have been delivered by the Rail Manufacturing CRC. This has included annual PhD students’ forums with guest presentations from senior rail industry representatives, student tours of industry headquarters in Melbourne, Sydney and Brisbane, the trial of a mentoring program to match students with rail industry representatives, and the rollout of a Grow Your Career job and research readiness training program to build the students’ skills in communicating research results, using LinkedIn, developing resumes and cover letters, and conducting interviews.

⁸ ACIL Tasman, Railway Manufacturing Industry: A profile of the Railway Manufacturing Industry, prepared for the Department of Innovation, Industry, Science and Research, July 2011.

Education and training programs in areas of skills shortage

A strong, efficient and modern rail industry is an important element of Australia's transport infrastructure future. With Australia's vast geography and distance from the sites of resource production to ports, coupled with high levels of urban congestion in growing cities, the country's future prosperity and productivity is dependent on a strong rail industry sector.

The rail industry is facing significant technological challenges including new manufacturing processes, automation and advancements in materials technologies. The sector can take advantage of these challenges by:

- » forging new alliances and collaboration to increase the rate of domestic innovation
- » upskilling the rail industry to include managers and staff that have a broad understanding of the current Science, Technology, Engineering and Mathematics (STEM) landscape
- » working to attract a younger and more diverse workforce
- » collaborating with a broader cross section of the transport and research sectors to gain a more holistic view of future innovation and economic opportunities.



Students participating at Melbourne PhD Students' Forum in March 2019



University of Wollongong PhD student Chuhao Liu has achieved multiple awards for his PhD pitching

CASE STUDY

The power of pitching

A PhD student's ability to communicate their research clearly and powerfully can determine their future. Often brilliant in their field of research, this doesn't always show when communicating the topic to prospective employers, a funding body or even a colleague.

Working with external trainers, the Centre's PhD students participated in PowerPitch training to learn how to write and deliver an engaging three-minute pitch about their PhD research. Throughout 2018, six of the PhD students were also given the opportunity to deliver their pitches to industry and university representatives attending the Rail Manufacturing CRC Participants Forums held in Sydney and Melbourne.

The Centre's students also had the chance to enter the CRC Association's Early Researcher Showcase competition in 2018. University of Wollongong student Chuhao Liu was selected as a finalist to present a five-minute pitch about his research during the conference, alongside five other PhD students working on other CRC-related research.

Chuhao's passionate, energising and funny pitch was selected as the winner by the 200 strong audience, and he was awarded his prize at the CRC Association's gala dinner in May 2018. He was also crowned overall winner of University of Wollongong's Three Minute Thesis competition that year, going on to compete in the Asia-Pacific 3MT Competition finals at the University of Queensland in September 2018. In September 2019, Chuhao was also selected as a finalist in the AusRail Young Professionals pitching competition.

Value statements from Rail Manufacturing CRC Research Participants

"CSIRO has been working with the Rail Manufacturing CRC on a variety of projects spanning many years. Our partnership with RMCRC has enabled us to better engage with the rail industry both locally and internationally and help to position Australia as a world leader in rail manufacturing research and development.

Through our projects together – and by harnessing the industry connections RMCRC has helped to broker – we have increased train network productivity, enhanced safety and improved performance. CSIRO and Australian industry are now well positioned to improve global rail operations for generations to come."

Keith McLean, Director Manufacturing – CSIRO



"UTS currently participates in eight CRCs, we see them as an excellent platform for delivering high impact from our collaborative research with industry. UTS enjoys a very productive relationship with the Rail Manufacturing CRC with a number of valuable research outcomes having been created through the collaborative research projects undertaken. It is particularly pleasing to note that these projects span across different discipline areas showing how the Rail Manufacturing CRC appeals to a wide range of industry interests and that UTS researchers work together to bring a diversity of expertise and perspectives to bear to meet those demands.

UTS strongly values the relationship it has developed with the Rail Manufacturing CRC. This can be attributed to having open channels of communication with the CRC team, so that irrespective of whether projects are progressing well, or if for some reason have stalled, it's always easy to have those helpful transparent and pragmatic conversations and to work together to deliver valuable outcomes. With the Rail Manufacturing CRC, those conversations are very easily facilitated, especially when they are done in a spirit of seeking solutions."

Kate McGrath, Deputy Vice-Chancellor (Research)
– University of Technology Sydney



Snapshot summary

Major achievements

- » Dwell Track™ passenger tracking technology patented, trademarked and trialled by the Sydney Trains rail network, commencing in August 2019
- » Projects between CSIRO and CRRC resulted in key gains in supercapacitor technologies and impending commercial trials of the developed energy management system
- » Arc welding software used by CRRC enabling optimised welding parameters to be determined
- » Bombardier and University of Queensland axle bearing projects providing the ability to understand wear and maintenance cycles of bearings, where optimised maintenance cycles are projected to provide a substantial return on project investment
- » The Smart Rail Route Map process brought together rail industry leaders to develop a digital roadmap for the next 30 years and to support the implementation of solutions through an industry-led steering committee
- » Airlinx has completed computational fluid dynamics modelling on air conditioning diffusers and airflow in train cabins to develop a model for improved thermal and air quality properties

Research

- » Research in the manufacturing processes and durability of rail components has focussed on protective coatings, stability of ballast, laser repair, new brake materials and enhanced welding processes
- » Development of new battery materials, cell properties and energy management systems to progress the commercial viability of energy storage systems in the rail sector
- » Technology, processes and design to reduce dwell time at train stations, including in the patent of Dwell Track™ technology
- » Advanced techniques for assessing rail infrastructure and rolling stock condition using unmanned aerial vehicles, sensors and predictive algorithms
- » Manufacturing and maintenance process efficiency using robotics, and virtual and augmented reality

Commercialisation and utilisation

- » All commercial outcomes and Intellectual Property terms and conditions are determined at project commencement, limiting any potential IP legacy issues in future years
- » Completion of projects in areas including supercapacitor development, axle bearing modelling, responsive passenger information systems and smart rail route mapping
- » Development of new battery and supercapacitor materials with far-reaching applications in rail, including potential use in the development of hybrid trains or catenary-free tram systems
- » Optimisation of maintenance and overhaul requirements for rolling stock by examining methods to model and predict lubrication needs, which may enable considerable financial and time savings for Australian passenger rail fleet operators
- » Following technology trial by Sydney Trains, it is anticipated that Dwell Track™ passenger tracking technology will be available to the Australian market through Downer
- » The use of cold spray to maintain and prolong coupler lifetime

SME engagement

- » Seven SME organisations participating in industry projects
- » Employment of a Business Development Manager in the Centre's early stages to specifically engage with SMEs
- » Proactive engagement with SMEs through Participants forums, key rail conferences, rail peak body events, and Federal and State Government forums
- » Regular strategic and tactical communications shared via recurring events, newsletters, website and social media updates, and face-to-face project meetings

Education and training

- » 48 PhD students supported in Centre lifetime across industry projects, scholarships and internships
- » To-date, two thesis submissions
- » Three students participating in an industry mentorship program trial
- » 40 students attending tours of industry headquarters across Melbourne, Brisbane and Sydney
- » Two PhD students' forums held
- » Six students pitching their research during rail industry events
- » Professional development training rolled out in Power Pitching and Grow Your Career job and research readiness program

Spin-off companies and inventions

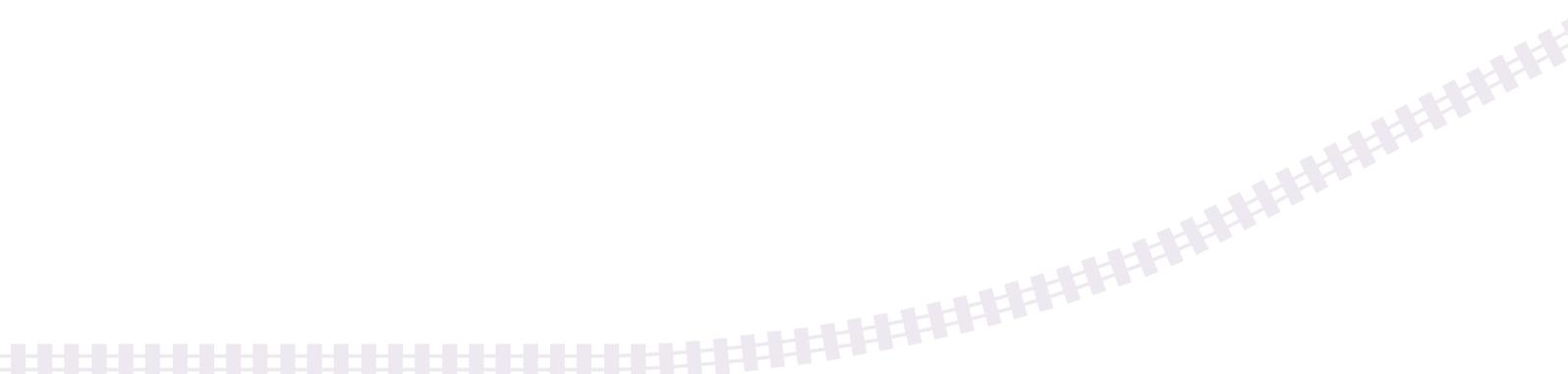
- » Trademarked by Downer and patented by the University of Technology Sydney, Dwell Track™ dwell time technology trialled by Sydney Trains network
- » University of Queensland's development of a software model and tool to extend the life of bearings operating well below their fatigue threshold
- » CSIRO and CRRC arc welding modelling software to predict the properties of rail welds, where accurate predictions are expected to greatly reduce the number of experimental tests required when developing weld designs for rolling stock fabrication

International engagement

- » Meeting with leading international rail organisations during participation in two Australian contingent visits to InnoTrans in 2016 and 2018
- » Site visits to MTU Engines in Germany, Swiss company Stadler in Switzerland and the HEC Group in China
- » Regular visits between CSIRO in Melbourne and Sydney and CRRC in China to support information transfer and the testing of supercapacitor technologies
- » Involvement in international events representing Chinese, Spanish and Indian rail conglomerates
- » Ongoing engagement with new international entries to the Australian rail industry
- » Delivery of eight projects with leading Chinese manufacturer CRRC, and working with multinational company HEC Group on its first two R&D projects in Australia in battery and supercapacitor development projects
- » CSIRO Researcher Dr. Marzi Barghamadi awarded an Endeavour Research Fellowship to work at Münster Electrochemical Energy Technology in Germany for three months to learn about Li-ion battery manufacturing
- » Monash University PhD student Wenhua Jiang studying at Massachusetts Institute of Technology (MIT) for six months in her research focus area of passenger flow forecasting

Glossary of terms

ACRI	Australasian Centre for Rail Innovation
ACNC	Australian Charities and Not-for-profits Commission
AMGC	Advanced Manufacturing Growth Centre
ARA	Australasian Railway Association
ARBC	Audit and Risk Board Committee
ASIC	Australian Securities and Investments Commission
CFD	Computational Fluid Dynamics
CQU	Central Queensland University
CRC	Cooperative Research Centre
CRRC	China Railway Rolling Stock Corporation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Essential Participant (or 'EP')	Those persons, bodies and organisations who provide essential support (including cash or in-kind contributions) for the activities of the CRC
HVAC	Heating, ventilation and cooling
ICN	Industry Capability Network
IP	Intellectual Property
Other Participant	A Participant who is not an Essential Participant who has signed an agreement with the CRC
QUT	Queensland University of Technology
R&D	Research and Development
RDDB	Research and Development Board Committee
RDMC	Research and Development Management Committee
RISSB	Rail Industry Safety and Standards Board
RMCRC (or 'the Centre')	Rail Manufacturing CRC
RNBC	Remuneration and Nominations Board Committee
SMEs	Small-to-medium enterprises
TSA	Tyre Stewardship Australia
UQ	University of Queensland
UTS	University of Technology Sydney
UoW	University of Wollongong





Rail Manufacturing CRC Ltd.

ABN – 14 600 249 518

PO Box 273

Flemington Victoria 3031

Australia

Ph: +61 3 8589 7112

www.rmcr.com.au