Research Manitoba

Composites and Biocomposites Research in Manitoba

An impact narrative

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List of Acronyms

CAD	Computer Aided Design
CCMRD	Canadian Composites Manufacturing R&D Inc.
CEO	Chief Executive Officer
CFI	Canada Foundation for Innovation
CIC	Composites Innovation Centre
CRIAQ	Consortium for Research and Innovation in Aerospace in Quebec
CRN	Composites Research Network
EIT	Engineer in Training
IRC	Industrial Research Chairs
MCI	Motor Coach Industries
NRC	National Research Council Canada
NRC-IRAP	National Research Council Canada Industrial Research Assistance Program
NSERC	Natural Sciences and Engineering Research Council of Canada
RRC	Red River College
RTM Light	Resin Transfer Moulding Light
SCI	Sande Curling Innovations
UMSAE	University of Manitoba Student Chapter of SAE International
VP	Vice President
WD	Western Economic Diversification Canada

Key Terms

Biocomposite	A biocomposite is a specific type of composite that uses natural fibres e.g. flax, hemp, agave, recycled wood, or food drop by-products.
Composite	A composite is a combination of two or more distinct materials that have superior properties together than they do apart.
Commercialization	Refers to a process that will to the creation or a product that may be sold after it has been created.
Fibre	A thread that is made of synthetic or natural materials and utilized to create a product.
Pre-commercialization	Refers to a process, but there is no product that is immediately viable for sale upon the completion of the process. The results of pre-commercialization may eventually be utilized for commercialization.
Resin	A material that may be used to bond other materials together.
Technology transfer	An industry term referring to the process of converting academic concepts and lab findings to technologies that address industry needs.

EXECUTIVE SUMMARY

In Manitoba, composites and biocomposites research formally started with the establishment of the Composites Innovation Centre (CIC), a not-for-profit corporation in 2003. The goal of the organization is to support and stimulate the growth of the composites sector in Manitoba and Canada through the application of composites materials and technologies for manufacturing industries. Today, as a leader in the composites application sector, the CIC has become well known for its groundbreaking research activities and discoveries across various sectors such as, aerospace, mining, curling sport, and ground transportation. the CIC has collaborated with industry partners such as Boeing Canada, Rockwell Collins (formerly known as B/E Aerospace), Motor Coach Industries, New Flyer Industries, Sandvik, and Buhler over the past 13 years to bring about catalytic growth in the composites sector of Manitoba.

To highlight the achievements of composites research in Manitoba, an impact narrative has been developed by Research Manitoba to (1) link the outcomes and impacts to the original research, and (2) communicate the impacts of research to a wide variety of audiences such as academics, industry members, community groups, the public and other users of research findings. The impact narrative on composites shows how the research work conducted by CIC and its clients unfolded into many impacts that can now be observed. Data was obtained from interviews with CEOs and project managers, and industry partners as well as documents shared by CIC e.g. annual reports and project summaries with Research Manitoba, and lastly publicly available information on the internet.

To illustrate the wide-ranging impact of composites, the narrative focused on four projects: an operating system enclosure for Sandvik to be used in harsh mining conditions; an interior panel created in partnership with Rockwell Collins for a Pilatus aircraft; cutting edge technology (i.e. a new resin system) for designing and manufacturing baggage doors of Motor Coach Industries (MCI), that was later adopted by most of the ground transportation industry in Manitoba; and, the development of broom handles and heads for the sport of curling with Sande Curling Innovations (SCI).

Research impacts on composites can be categorized into four areas: advancing knowledge through discoveries from research, building capacity in the composites sector, informing decision making, and economic impacts:

Advancing Knowledge: the research partnerships with industry has led to new discoveries and the applications of research findings. For instance, impact testing of different materials enabled the building of a control panel enclosure for Sandvik, one that is apt for severe mining conditions. CIC has also developed a new resin system for creating lighter, economical and more robust baggage doors for MCI. Additionally, CIC invested its resources in revolutionizing the existing market products of its clients. The curling broom handle and head developed for SCI is superior than the traditional ones, because of its durability and player friendly features. After several rounds of Computer Aided Design (CAD) modelling, prototype designing, and stress analysis testing in the lab, CIC helped SCI develop new broom handles and heads that can be produced on a commercial scale. Similarly, the combined effort of CIC and

Rockwell Collins resulted in the creation of an efficient and high-valued interior door panel. CIC's team contributed in CAD modelling and designing to successfully devise the panel, which with the inclusion of composites made the manufacturing process more efficient. Other innovative discoveries by CIC include, the Green Garage project, situated in The Alternative Village in University of Manitoba which is made entirely of sustainable components, and, FibreCITY, the world's first and foremost biofibre grading database. FibreCITY speeds up the process of assessing and selecting superior quality fibre crops for quicker manufacturing procedures.

Building Capacity: The CIC has provided hands-on training to help build the capacity of CIC members and researchers/students as well as industry partners. For example, students have been able to complete internships and subsequently been employed by CIC or in the composite industry. Additionally, the CIC has also helped mentor the staff of its private sector partners through direct project involvement and formal training such as the composite industry technician training program for hand layup, infusion moulding, and tool manufacturing. Furthermore, another training session regularly carried out by CIC informs private stakeholders about the importance and benefits of integrating composites into their products, new product designs using composites, and composite process demonstrations. Overall, these activities have help to strengthen the capabilities and scope of the composite industry in Manitoba.

Informing Decision Making: The CIC has provided research support to private companies pursing their goals, whether it be in developing new processes such as MCI with the new manufacturing system for baggage doors, or developing radical new products such as with SCI with its revolutionary broom handles and heads. In the public sector, it has engaged with provincial and federal governments to influence policy development that positively impacts the composite industry in Manitoba. One example is the aid of the CIC in developing Growing Green, the Manitoba Bioproducts Strategy that supports the creation of a bioproducts industry using agricultural biomass. Additionally, the CIC also led a program entitled BioNet Manitoba which facilitated the growth of bioproducts supply chains by drawing the attention of the industry, producers, and government. Due to the previous success of CIC supported projects in the industry as well as networking events and presence, the CIC has been able to successfully articulate the value of investment in the Manitoba composite industry.

Economic Impacts: Finally, the measurable economic impact of the numerous CIC projects includes: the creation of new jobs in the province, the creation of new or the improvement of commercial products, and boosting the sales and manufacturing capacities of its private sector partners, which in turn boosts the provincial economy.

The future of composites and biocomposites in Manitoba is very promising and CIC will continue to play a strong role in the growth of this sector. Specifically, by assisting industry in developing new commercial opportunities and advancing existing technologies by integrating composites. Presently, Canada has established strong aerospace and ground transportation sectors and demand in the usage of composites in the bodies of aircrafts and ground vehicles will likely increase as the world seeks to reduce greenhouse emissions and manufacturers turn to materials that are lighter. In the future the CIC plans to continue to work with their partners in these two industries as well as others to create new industry consortia and research networks that stimulate novel and advanced research in the composite sector thereby attracting new investors.

Part I: Introduction

1. Background

Research Manitoba develops impact narratives to document the outcomes and impacts of research in the province. The goal of the impact narrative is two-fold: a) to link outcomes and impacts to the original research, and b) to communicate the impacts of research to a wide variety of audiences such as government, academics, industry, community groups, the public and other users of research findings. The narrative also contributes to the following goals of Research Manitoba in measuring impacts:

- Determine the return on investment of Research Manitoba's funded programs and projects;
- Inform Research Manitoba's decision making, planning and programming;
- Record accountability and transparency (a reporting tool to the Government of Manitoba – Dept. of Growth, Enterprise & Trade);
- Encourage a proactive and prospective measurement and monitoring of research impacts among researchers, funders and users of knowledge; and,
- Contribute to the growing practice of research impact assessment in Canada and globally.

2. About Composites and Biocomposites

Canada is home to many composites users and the demand is driven by the aerospace, transportation, building and construction, sports equipment and leisure, and other sectors. Since 1960, the market has been growing by 6% annually.[1] In 2014, it was estimated that the "North America[n] composites market accounts for 36% ($22 billion) of the global composites industry and 35% (3 million metric tons) in volume."[2] There are approximately 300 composite companies that employs 50,000 people in Canada.[3] Financial stability, an educated workforce, market access, and research and development give Canada the competitive advantage over other countries and boosts its composites sector.[4] Canadian investment in university research and development in advanced composites has also grown over the years and is relatively high compared to international standards.[5] University of Manitoba is one of 23 universities that have composite research programs.[6]

According to a 2013 survey conducted by the Composites Research Network, out of four western provinces in Canada, Manitoba has been the most significant revenue earner and job creator in the field of composites.[7] A composite is a combination of two or more distinct materials that have superior properties together than they do apart. Composites typically contain two parts; the first is the matrix, otherwise known as resin, and the second is the fibres. The resulting material has superior structural properties compared to the particles that make it up. Biocomposites on the other hand use natural fibres instead of the common synthetic fibres such as carbon, glass or aramid. These fibres can be extracted from natural sources like flax, hemp, agave, recycled wood or can even come from by-products of food crops.[8]

Manitoba is rich with a large variety of natural fibres such as wheat, flax and hemp, which gives the province a competitive edge to prosper in the field of biocomposites.[9] With the abundance of natural materials and the strong presence of producers, Manitoba attracts and supports industry engagement and research to advance the biocomposites industry.

Composites users have a strong presence in Manitoba, since North America's largest bus manufacturer and aircraft manufacturer, New Flyer Industries and Boeing Canada, have manufacturing facilities located in Manitoba.[10] With the growing demand for composites, there is a need for service providers like the Composites Innovation Centre (CIC) to coordinate and promote the Manitoba composite industry. The CIC is an internationally recognized, not-for-profit organization based in Winnipeg that develops composite technologies for manufacturing companies such as Boeing Canada, New Flyer Industries, Motor Coach Industries, and many others. Specifically, The CIC helps to support and drive economic growth through innovative research and development with composites and biocomposites.[11]Due to an increasing need for lighter weight materials and reducing greenhouse emissions, The CIC primarily works in the Aerospace, Ground Vehicles, Industrial Products, and Bioproducts sectors.

3. About the Composites Innovation Centre (CIC)

Before the CIC started its operations, the biocomposites industry in Manitoba was comprised of only two companies, SWM International and Dow Bioproducts Ltd. Since there were just two companies operating independently of each other, it was suggested by some stakeholders that composite companies could have a more significant impact as a combined entity.

Stakeholders also recognized that Manitoba was lacking an organization that could help drive the development of the composites industry and simultaneously focus on four important areas:

- A technology centre: The centre would help to support development and also to fill in the technology gaps before bringing the finished product to the market.
- Availability of rural material supplier: This would ensure that the industry has access to abundant supply of the raw materials used to make biocomposites.
- Skills and training: Skilled workers would be needed to operate a growing industry and to further boost its expansion.
- Investment capital: The budding companies in this sector would require a constant source of funds to keep the operations running.[12]

This realization led to a series of surveys that were conducted with the support of the National Research Council Canada, the Government of Manitoba, and the City of Winnipeg. The positive response from the surveys led to the decision to establish the Composites Innovation Centre Manitoba Inc. (CIC) in 2003, an organization focused on the advancement of the composites industry and later, the biocomposites industry.

Today, the CIC drives economic growth through innovative research, development, and the application of composite materials/technologies for manufacturing industries.[13] Initially Mr. Sean McKay, President and CEO of the CIC, and another consultant, drafted the business plan and identified 27 potential projects. Funding for the preliminary projects was provided by Western Economic Diversification Canada, the Province of Manitoba, and also by a few private companies.[14]

The CIC began with providing project management and engineering services to industry partners. Additionally, the company was also coordinating with consultants and industry partners to support different kinds of composite projects. According to Mr. McKay, the CIC provides direct services to their industry partners in two ways; first, the company acts as a support system and second, it brings groups of networks together, which are capable of providing support to various industry organizations.[15]

Canada currently views the CIC as a leader in the field of composites and biocomposites research. To come to this stage, the company has successfully completed several projects and established numerous important networks within the composite industry. The CIC is accelerating the long-term growth of Western Canadian composites manufacturers, original equipment manufacturers (OEMs) and material processors. It does so by providing differentiated technical services, developing and implementing new technologies and building awareness of those services and technologies through global networks.[16]

The type of work undertaken by the CIC can be classified into two main categories: commercialization and pre-commercialization. Commercialization activities are those that lead to a product that can be used almost immediately. It happens when an industry partner is engaged in the project and at its completion, the partner will have a new product or technology that can be used. On the other hand, pre-commercialization activities are where the end result is a capability or a platform that the industry partner can adapt and move forward with, which can be operationalized, and the subsequent products can later be commercialized.

The CIC's support to industry is not streamlined into one category as its role varies depending on the industry sector and application. The CIC is well known as an organization that works directly with industry on commercialization activities like product design and development, material selection, testing, and prototyping. Further, the CIC is also currently focused on diversifying its services with the inclusion of pre-commercialization activities. As Mr. McKay mentioned during the interview, while the CIC's clients are "becoming more sophisticated and new opportunities are arising that are of interest to our partners (e.g. biomaterials, recycling), we have been increasing our level of efforts in the pre-commercialization area." Mr. McKay also notes that such undertakings are not the bulk of the activities performed by the CIC.

An example of a pre-commercialization activity is the aerospace consortium, Canadian Composites Manufacturing R&D Inc. (CCMRD), which coordinates large technology development programs and brings together research, academia and industry partners from all across Canada. The new technologies that come out of the consortium are shared with the members, who then have the opportunity to advance them into commercial applications. Another example is one of the CIC's ongoing projects, the Prairie Agricultural Fibre Characterization Industrial Technology (FibreCITY) initiative. FibreCITY is a centre of excellence for agricultural crop grading that supports and stimulates the biofibre industry through research, development and the application of biofibre knowledge to real-world applications. With FibreCITY, the CIC plans to shift the attention of manufacturers towards renewable materials and reform the materials industry with a “greener approach.”[17]

To sustain the CIC since 2003, funding has come from multiple sources. Since 2000, investments from the provincial and federal governments into composites-related infrastructure, research and technology development have multiplied. Some of the notable funders of research in the sector of composites are National Research Council Canada Industrial Research Assistance Program (NRC-IRAP), Western Economic Diversification Canada (WD), and the Government of Manitoba, Natural Sciences and Engineering Research Council of Canada (NSERC), Canada Foundation for Innovation (CFI), Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ), Industrial Research Chairs (IRC), and universities.[18] In 2015, Research Manitoba provided the CIC with $228,000 over a period of two years for a research project on advancing natural fibres for composite applications. The project focuses on collaboration with the University of Queensland in Australia and Tianjin Polytechnic University in China. This collaboration aims to develop an international consortium that will facilitate the development of crop varieties, which will give Canadian producers consistent quality and value from the crops and their components for the development of biocomposite materials.

To further accelerate the growth, stimulate innovation and drive research in the four bioproducts sector (biomaterials, biochemical, biofuel and bioenergy) of Canadian biomass industries, the CIC received $2.9 million funding in November 2016 from Agriculture and Agri-Food Canada (AAFC). Close to a million will be spent identifying quality gaps and developing quality standards and measurement techniques to facilitate the commercialization of Canadian biomass. The rest of the funding will be for research on how the strength and quality of composites can be affected by farming practices, varieties and weather.[19]

Alongside the public investors, there are several private companies ranging from original equipment manufacturers (OEMs), composite fabricators, service providers and technology centres that are spread across Canada and contribute to the fast growth of the composites sector.[20]

4. Role of the CIC in the composites and biocomposites industries

Over time, the CIC has modified its services to cater to the growing demand of composite industry partners, having started off with generating project management and engineering services by a handful of staff members. From there, the company has subsequently gained a wealth of knowledge and experience and now regarded as a leader in the composites and biocomposites industries, “the CIC continues to support the industry and has gradually assumed a leadership role in terms of fore sighting new technologies and creating capabilities,” said Mr. McKay.[21]

“We (the CIC) are a solutions provider for the composites industry,” said Mr. McKay. The company is now supporting the development of technologies and then taking those technologies and transferring them to benefit industry partners. The CIC is filling specific technology gaps using their engineering services, and bringing others to the table to support the industry.

In the composites industry, Boeing and the CIC have maintained a strong partnership which resulted in many successful collaborations over the decade.[22] Mr. Richard Laurin, Senior Manager of Boeing Winnipeg shared the company's experience with the CIC and said that, "The CIC team and facility have supported multiple investigations that otherwise would have required sending work out of the province to be performed. The CIC has been central in coordinating and managing the Canadian Composites Manufacturing Research and Development activities that Boeing participates in." [23]

Regarding biocomposites, the CIC is a leader in research and development to commercialize the use of natural fibres in industrial applications. To support this, the CIC has developed a strategy in partnership with Manitoba Agriculture to connect the producers to the consumers in a field-to-factory approach. This engages different stakeholders to support establishing the supply chain.

The various industry partners that the CIC has worked with have positive feedback regarding the quality of work and the commitment of the CIC in developing a product according to their needs. "As part of our 75th anniversary we would like to acknowledge the strategic importance of our relationship with the CIC who has given us the confidence to significantly grow our markets, products and technologies within and outside of Manitoba," said Mr. Neil Carlson, President of Carlson Engineered Composites Inc. [24]

Mr. Chad Brick, President of Eastside Industrial Coatings and Composites, has attributed their company's progress to the CIC's contribution and further added, "We could not have achieved our growth and success without the CIC's support. We continue to rely on the CIC to accelerate technology adoption to strengthen our supply chain and global competitiveness."[25]

"I think the CIC has been and continues to be a strong contributor to industry in the province", said Mr. Rick Jensen, Director, Government and Community Relations, Boeing Canada Technology, Winnipeg Division (Retired).[26] Acknowledging the role of the CIC as a support system to the industry Mr. Jensen said, "The CIC is very good at helping interested companies evaluate their requirements, from an engineering perspective, and recommend the appropriate approach to incorporate composite materials and the manufacturing processes needed to make these new products. They do this hand-in-hand with the client, both at CIC's facility and the client's site. There are numerous businesses that have now implemented these new capabilities into their operations and are growing in ways they would not have been able to without the CIC's guidance." [27]

5. Impact narrative approach/methodology

Outputs, outcomes and impacts in this narrative are examined through the lens of the Research Manitoba impact framework, which is divided into five categories:

- **Advancing knowledge** involves creation/co-creation of knowledge, new discoveries and breakthroughs arising from research, and contributions to the knowledge pool.

- **Building capacity** refers to the development and enhancement of the ability of individuals and teams to conduct and sustain research.
- **Influence on perceptions, thinking, awareness and decision making** because of research activities/findings can take numerous forms but largely refers to the influence and effects on government; industry; the research enterprise; not for profit organizations; individuals, groups and communities; educational institutions; and the public.
- **Applications and changes** are the outcomes and impacts that result from research in health, social sciences and humanities, and natural sciences and engineering disciplines.
- **Broad benefits** include economic, technological, environmental, social/societal, and cultural benefits impacts such as wellbeing and prosperity**.**

This impact narrative will focus on the role the CIC has as a leader in the composites industry, developing new technologies in Manitoba and Western Canada. The company has revolutionized the use of composites in Canada by promoting their importance and developing essential connections between private companies and stakeholders in this sector. By working with 154 industry members and 40 agency partners to date, the company has received accolades at the national as well as international level for its innovative work in composites and biocomposites.[28]

To identify and understand the extent of the impacts as well as the work of the CIC, the narrative poses two evaluation questions:

- What are the impacts that the CIC has helped bring about in the Manitoba composites industry?
- To what extent has the CIC's collaborations with private companies/partners contributed to its mission/goals?

Contribution analysis or a theory of change model is used to respond to these questions thereby illustrating how the CIC's activities such as research and development, technology transfer activities, and collaborations have led to the outcomes and impacts which are observed now. Technology transfer is an industry term referring to the process of converting academic concepts and lab findings to technologies that address industry needs. Contribution analysis is a causal model that shows the links between activities, outputs and outcomes.[29] Through this model, selected projects show how the CIC's activities have contributed to its goal of supporting industry and commercializing composite technologies. The links between the CIC's activities and the subsequent impacts from its collaborations with industry are also identified, establishing the CIC's role in the impacts and how its work has contributed to the organizational goals.

To collect data for the impact narrative, a questionnaire was developed focusing on the inputs, outputs and outcomes of projects on composites (Appendix 1). Of the CIC's many successful projects, four were selected and the same questionnaire, with some project specific questions, was used. With the assistance of the CIC's Marketing and Communications Coordinator, the cooperation of the four companies was obtained.
To date, the CIC has successfully collaborated with numerous partners and implemented many projects bound by confidentiality agreements. Hence, the company is not able to share data on the work for all the projects

that the company has undertaken since its beginning. After meeting with the CIC, the following projects were selected and agreed upon:

- Sandvik Eris Control Panel,
- Rockwell Collins Composite Interior Panel,
- Motor Coach Industries (MCI) Baggage Door, and
- Sande Curling Innovations (SCI) Curling Broom and Brush Head.

To gather information, interviews were carried out with the President and CEO of the CIC and the Project Managers of the four projects:

- Sean McKay, President and CEO of the CIC
- Alastair Komus, Principal Engineer, Ground Vehicles and Design, CIC. Project Manager of Sandvik Eris Control Panel and Sande Curling Innovations (SCI) Curling Broom and Brush Head projects.
- Steve Crouch, Principal Engineer, Engineer in Training (EIT) Aerospace, Materials and Processes, CIC. Project Manager of the Rockwell Collins Composite Interior Panel project.
- Mark Townsley, Vice President, Ground Vehicles and Design, CIC. Project Manager of the Motor Coach Industries (MCI) Baggage Door project.

Additional data was collected from project documents, the CIC's website, a booklet made by the CIC, the internet (e.g. websites of the CIC's clients or partners), phone conversations with representatives of Sandvik and Rockwell Collins and testimonials from industry members on the role and impact of the CIC on their companies.

A part-time person (Ms. Sanchita Sarker) was recruited and worked with Ambrosio Catalla Jr, Evaluation & Policy Analyst at Research Manitoba on this impact narrative from June to October 2016. Mr. Ryan Catte, M.A., Evaluation Assistant, contributed to the report.

6. Limitations

This narrative could not have been successfully completed without the support from the CIC's team and its industry partners. Although most of the information in this impact narrative was available through project documents and interviews, several constraints were experienced:

- Non-disclosure agreements: Most of the clients that the CIC works with have a non-disclosure agreement for their projects. Consequently, it was not possible to quantify certain types of impact such as revenues/sales. As an example, for the Rockwell Collins Interior Composite Panel project, a considerable amount of information remains missing in the narrative due to non-disclosure agreements. The total funding for the project was obtained from different sources. The economic impact gained through sales, number and name of projects where the manufacturing technology was used by the company was not provided as well.
- Time is figured as a limitation in some of the projects. For example, the MCI and Rockwell Collins projects took place some time ago, making it difficult to determine the role of a few team members.

- Limited participation: Perspectives of other leaders were sought on the role of the CIC and its contributions to the industry. However, despite the help of the Marketing and Communications Coordinator from the CIC, limited response was obtained.
- Bibliometric analysis: Generally, most of the work carried out by the CIC and its partners was more applied in nature. Although reports were prepared, these were used only by the partners, and with their agreement, by the CIC. Reports were not published in journals, hence bibliometric data and analysis are absent from this report.
- Quantitative measures such as leveraged amounts as well as proxy measures of return on investments cannot be estimated due to limited access to data. The CIC's partners are private companies and did not share data that would enable the calculation of these measures.

PART II: Findings

To date, the CIC has worked with renowned companies such as Boeing Canada, New Flyer Industries, Buhler Versatile and many more. Additionally, the CIC has also carried out numerous seminars, workshops and training programs to raise awareness about the benefits of using composites. All four of these projects are considered to be commercialization activities and are discussed separately below.

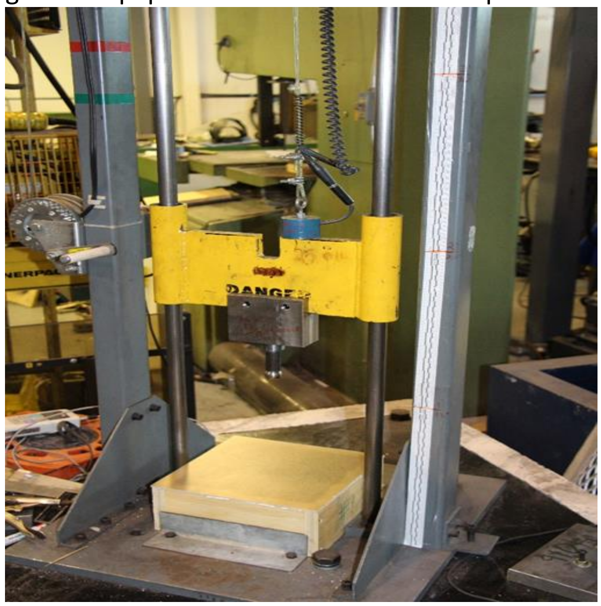
1. Sandvik Eris Control Panel Project

Sandvik Mining is a provider of a wide-range of equipment, tools, services and solutions that help the global mining industry excavate, transport and process ore, safely and productively.[30] The project was initiated after Mr. Mark Townsley, Vice President of Ground Vehicles and Design at the CIC, met a staff member from Sandvik (formerly known as Cubex). The primary purpose of the project was to reduce the manufacturing costs of the case for the operating system while maintaining its current performance. Although, the resulting savings on weight because of the use of composites were considered an added benefit.

The CIC and Sandvik formally agreed on August 15, 2013, to develop a new composite enclosure for the Eris Control Panel system used to control mining equipment. The goal was to ensure the new enclosure could withstand the harsh mining environment and at the same time reduce manufacturing costs.[31]

The CIC team designed the enclosure to fit the control panel using CAD software. The CIC performed impact testing in tandem with the design phase. They needed to identify the materials, so they could determine the required wall thickness before they finalized the design. This process involved testing with different combinations of materials to select the type that would be most resistant to damage. It was essential to test this since the control panel was going to be used in severe mining conditions and harsh environments. The impact testing was carried out by the CIC at the Industrial Centre Technology. They tested basalt fibres and fibreglass and selected the fibreglass because it showed less damage after impact. After the completion of the initial work on the enclosure, a prototype was built and tested.

Figure 1. Equipment used in the lab for impact testing[32]



The prototype was sent to one of Sandvik's client's mines in Thompson, Manitoba, to test its suitability in real-life mining conditions. At this point the supplier discontinued the panel and Sandvik had to switch screens and as a result, the enclosure design had to be adjusted. This meant that CIC had to resize the opening of the panel and also incorporate minor changes to the first prototype. By August 2014, the CIC completed all the necessary changes and the next phase of testing began. The final enclosure designs were handed over to Sandvik in 2015. The company then went on to commercially manufacture the control panel in May 2016.

a. Inputs: funding and people

The project received $21,875 in total from Sandvik and the CIC. The main portion of the funding was used towards design and development of the product.

The project team consisted of engineers who were involved in designing and testing the product and two students who later became full-time employees of the CIC. While working on the project, the team developed skills related to impact testing, as they were carrying out various lab tests to measure the strength of the materials. The two university students had the opportunity to expand their knowledge on CAD modelling and project management as well. A detailed description of the roles of the team members is in Appendix 2.

Besides the team members from the CIC, there were other partners who played an important role in developing and assembling the new control panel enclosure including:

- Eastside Industrial Coatings and Composites manufactured the fibreglass for the control panel and provided feedback on the ideal shape and size of the fibreglass for the panel.
- Hi-Tec Industries supplied the metal tapping plates and fasteners.

- Sandvik provided significant technical and human capital resources for the project. Five people from the company were associated over the course of the project. Besides providing the electronic equipment, Sandvik also helped in the development of the design of the control panel by determining the shape and size for better product suitability.
- State Industries supplied the rubber corners for the enclosure.

The feedback from all these companies helped the CIC integrate all the technical inputs and develop the final product.

b. Outputs

Informing the CIC's work

Although the results of the impact tests from the laboratory were not formally documented and published, they are a valuable resource for the CIC in other projects. For instance, the results were applied to three other projects.[33] For instance, the CIC built a step-over component for an amusement park ride where it was essential that the component was made with an impact resistant material, since passengers step on it before getting onboard. The knowledge on material properties that the team gained from the Eris Control Panel project helped them decide on the type of material to be used for the step-over component.

Building the capacity of students and the CIC staff

The project enabled the Junior Engineers as well as the students to acquire knowledge, skills and experience in product design and development using composites. Mr. Cheung and Mr. Lagunera, both had the opportunity to advance their knowledge on design and impact testing. Additionally, the team members investigated various materials that would be most appropriate for the enclosure, giving them experience they could apply later in their careers. It was also a learning experience for the two students involved in the project, Ms. Kincaid and Ms. Beley, and the project helped to open the door for them to secure full-time positions at the CIC.

c. Outcomes

Addition of a new product design capability for Sandvik

Collaborating with the CIC to develop a new enclosure, Sandvik was exposed to a new kind of technology, a novel experience for the company. With the newly developed enclosure, the company added the composite material as one of their product design capabilities.

Sales volume

Since the beginning of production through 2014, Sandvik has sold 20 enclosure units. During this period, Sandvik encountered a technical issue with the panel screen which delayed production by a year resulting in reduced sales for a short time. After redesigning the composite housing for the new screens, Sandvik started producing more of the new composite. Sandvik is projecting sales to increase five-fold by the year 2018.[34] There is potential for growth as the company has an extensive supply network spread across several continents and it is currently offering mining equipment to 130 countries.[35]

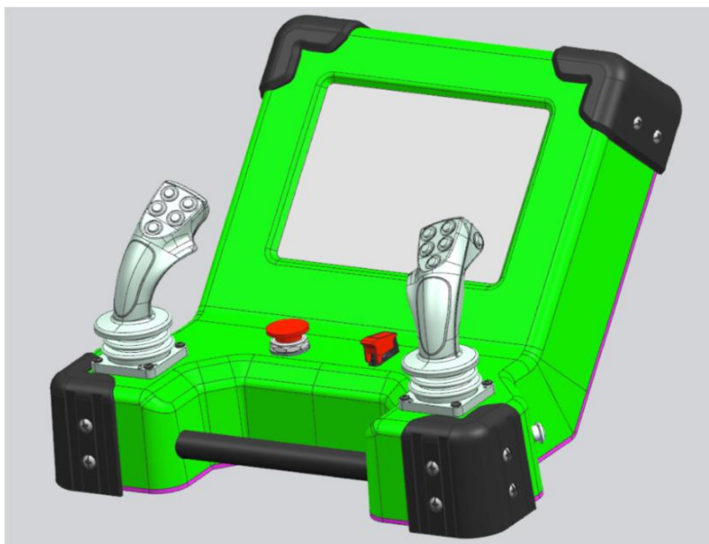
Cost reduction per unit of the panel

As a result of the project, each unit of the Sandvik Eris Control Panel can be manufactured at 20% of the original cost of production, which translates to a 20% increase in profit margin per panel.[36] This cost reduction helped Sandvik earn higher profit margins while preserving the performance of the product.

Longer lifespan of product

The new enclosure protects the panel from moisture as well as the wear and tear of being used in the harsh mining environment. With the new enclosure, the panel was sealed tightly, which helped to reduce the chances of the equipment becoming exposed to moisture and preserving the product's quality for a longer time period.[37]

Figure 2. Final design of the Sandvik Eris Control Panel[38]



Impact on the Manitoba economy

As a made-in-Manitoba product, the Sandvik Eris Control Panel enclosure helped boost the economy of the province. All components in the enclosure were manufactured in Manitoba. For instance, the fibreglass enclosure was manufactured by Eastside Industrial Coatings and Composites, the tapping plates were made by Hi-Tec Industries and the rubber corner bumpers were provided by State Industries. As Sandvik continues to expand its production, the involvement of these companies will grow. This in turn will lead to more jobs, boosting the growth of the industrial sector in Manitoba.

Job creation

New jobs were created in Eastside Industrial Coatings and Composites, although this has not been confirmed by the company.[39] But at the CIC, several jobs were sustained, and the two students involved in the project were later employed by the CIC full-time.

d. Challenges faced while working on Sandvik Eris Control Panel project

- Design tradeoff: In the design phase of the project it was difficult to balance the durability of a material type, the cost and fitting all the components together.
- Finding the right material for the enclosure: While testing materials to help select the best one for the enclosure, it was important to keep in mind that the material would need to be strong and resilient enough to cope with the harsh mining environment.
- Designing a waterproof enclosure: The CIC needed to incorporate special design features to ensure the entire enclosure was waterproof and remained waterproof through being used in the mining environment.

2. Rockwell Collins Composite Interior Panel Project

Rockwell Collins is the world's leading aircraft manufacturer of cabin interior products for the aviation industry which includes seating, electronic systems, oxygen masks, passenger service unit systems and more.[40] The company also offers seating services, gallery inserts such as beverage makers, as well as refrigeration and oven products for cabins.

From private air transport companies to government systems, the company serves a wide range of markets. Besides manufacturing, the company also assembles, integrates and supports the installation of their products. To remain competitive in the aerospace industry, Rockwell Collins channels its resources towards developing an efficient manufacturing process to reduce the cost of manufacturing and consequently sell their products for a competitive price.

Having previously worked together on feasibility studies for other products, Rockwell Collins approached the CIC in April 2013 for assistance in developing a new access door made with composites for the Pilatus aircraft. As a part of the project agreement, the CIC provided technical assistance to Rockwell Collins for the development of an interior panel system to support a new cargo and utility door modification. By the end of the contract, the CIC had assisted Rockwell Collins in adopting new technologies and capabilities including self-heated tooling for composite production, layup and bagging of complex geometries and expanding their manufacturing quality system to support composite production. The CIC also supported the development of requirements for facilities and equipment identification for composite manufacturing operations.

The project involved a successful collaboration among the CIC, Composites Research Network (CRN) and Rockwell Collins. While most of the project work took place in Rockwell Collins's industrial site and CRN provided additional technical equipment, the CIC undertook the product testing in its laboratory. Mr. David Vanderzwaag, the current Programs Manager of Rockwell Collins, said "The CIC has been instrumental in providing Rockwell Collins with the resources and guidance to successfully launch a new capability that delivered first-class results right out of the gate."

In addition to working with the CIC and CRN, Rockwell Collins joined the Canadian Composites Manufacturing Research and Development (CCMRD), a consortium that was founded and implemented by Boeing with the support of CIC, which enables the collaboration of precompetitive research with aerospace companies all across Canada.[41] Rockwell Collins joined the consortium for a year, soon after starting work on the project on the interior door panel with the CIC. During its one-year association with the consortium, Rockwell Collins had exposure to new capabilities which helped them develop their abilities in new manufacturing technologies.[42]

a. Inputs: funding and people

Approximately $400,000 was required for the project coming from Rockwell Collins and the CIC and in-kind support was provided by CRN.

Over four months, engineers and students from CRN, the CIC and Rockwell Collins joined forces for successful completion of the composite interior panel project. Three people from CRN, four from the CIC and four from Rockwell Collins were involved in different phases of the project.

The CIC provided on-site technical support, developed draft specifications and quality standards, assisted in manufacturing process development trials and provided support in first article manufacture. CRN provided on-site technical support and assisted in performing evaluations on process trials and supported first article manufacture. Rockwell Collins led panel design, facilities upgrades, staff training, finalized new process and quality specifications and implemented the production.

b. Outputs

Building the capacity of students and the CIC staff

The capacity that students and the CIC staff now possess was built in two ways: through the direct involvement in the project and by participating in a workshop on “How to do composite layup of very complicated geometries.”

Knowledge and skills gained from project

This project helped many students gain valuable experience. The student from CRN, Mr. Xiong, was engaged in manufacturing and testing of the project which provided him with insights on composite manufacturing processes.

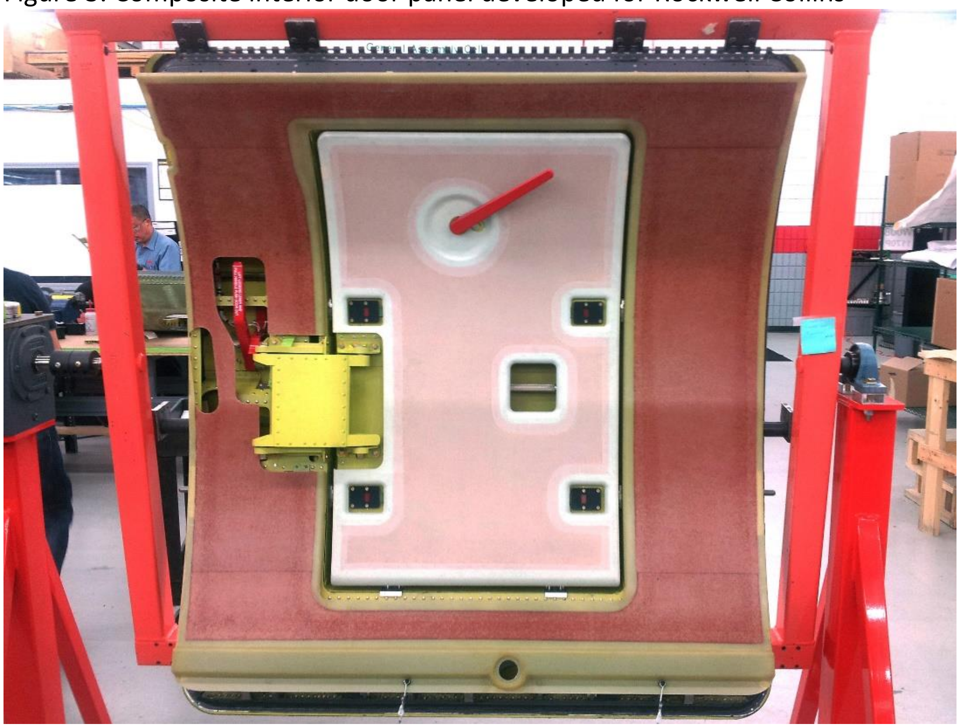
The CIC organized a “Complex Layup and Bagging Workshop” with support from Boeing to learn techniques on how to layup complex geometries. The skills to design of experiments was learned from a previous project the CIC had completed with Rockwell Collins in which they brought in an expert to provide a training session.

The content of the workshop that was used earlier to train the staff members was later integrated in training sessions provided by the CIC, including those provided to the University of Manitoba SAE (UMSAE). UMSAE provides the students an opportunity to apply their classroom knowledge in real-life situations by taking part in various automotive and other industry sector competitions.[43] In order to assist these students on the technical know-hows and acquaint them with manufacturing procedures, the CIC conducts training sessions at their facility. A course on composite design is also offered to demonstrate the best practices of using composites.

Developing a new capability

By the end of the project, the CIC successfully helped Rockwell Collins add a brand-new capability for the interior panel production and helped them gain exposure to new manufacturing technologies. This innovative ability helped to revamp the company's production capabilities. The new manufacturing technology also gave the company a competitive edge.

Figure 3. Composite interior door panel developed for Rockwell Collins[44]



c. Outcomes

Economic impact on Rockwell Collins

The company received an order for 18 aircrafts with composites interior door panel in 2013, prior to the project beginning.[45] The aircraft that was used for the order had an inward opening utility door installed, which was created with the new manufacturing technology. This new manufacturing process also enhanced the design and production capacity of Rockwell Collins, which in turn helped the company to attract more stakeholders, leading to more projects and expanding their supply chain.[46]

Job creation

Soon after the start of the project, Rockwell Collins hired a new person for their production facility. More people were hired eventually when the door panel started to be produced commercially. According to an article in Winnipeg Free Press published in September 2013, Rockwell Collins increased its total number of employees from 53 in 2012 to over 100 in 2013.

d. Challenges faced while working on the composite interior panel

According to the Rockwell Collins Composite Interior Panel Project Manager, the biggest challenge was to efficiently fit in all the work in the specified timeline. "The first delivery was just 14 weeks from concept," said Mr. Crouch.[47] Over the course of four months, the team had to establish a new manufacturing capability, document the work and also deliver certified parts to the customer. The main concern for the team was coordinating their resources within this timeline, which they ultimately carried out effectively. The technical challenges faced by the team were handled through a collaborative effort.

3. Motor Coach Industries (MCI) Baggage Door

Motor Coach Industries (MCI) and the CIC collaborated to develop a lighter, more economical and robust baggage door for its intercity fleet.[48] After the identification of numerous technical gaps in the existing traditional doors by the teams from both companies, they found that improvements were required within the design, moulding processes and ease of fabrication, to improve the performance and cost of the doors.[49]

Serving a wide range of markets and with a diversified portfolio of vehicles, MCI is North America's leader in the supply and manufacture of intercity coaches.[50] MCI started its operations in Winnipeg in 1939 and also has an alternate plant located in Pembina, North Dakota to satisfy "buy America" requirements. The company has a wide array of products and sells vehicles to the public and private sectors.[51]

Mr. Mark Townsley, who is the Vice President of the Ground Vehicles and Design at the CIC, was working for MCI as a Senior Design and Materials Technologist when the project started. He was given the responsibility of reducing the manufacturing cost and weight of the vehicles to increase fuel economy. Mr. Townsley approached the CIC to support the development of a better method to manufacture the doors.[52] "The CIC were experts in composite design," said Mr. Townsley.[53] On February 23, 2005, the CIC and MCI formally agreed to start work on the project. The time span from the beginning to the end of the project was 16 months.

At the end of the project, the CIC helped to support the technology transfer of an innovative moulding technology for MCI, which improved the manufacturing efficiency of the lighter, cost-competitive baggage doors. Tests also showed that the resulting door design was more thermally stable compared to the conventional baggage doors. At the completion of the project, MCI conveyed its satisfaction in working with the CIC saying, "the CIC provided the tools and technical expertise to develop a product that is lighter and less expensive with all the key functional qualities required. We are now confident in our abilities to develop products based on the technical skills received from the CIC to set up and deliver complicated structural composite based products within our business," said Mr. Jim MacDonald, Executive Director of Engineering, MCI. He expressed his satisfaction in partnering with the CIC by saying, "the development and deployment of composite technologies is rapidly evolving; the CIC is an essential part of our engineering team, assisting MCI in keeping abreast of advances and improving our products in real time."[54]

a. Inputs: funding and people

The total funding required for this project was $82,043.

Four team members from the CIC were involved in the project. Most assisted in creating a structural design for the door, as well as processing the door in the research phase in the lab. Two University of Manitoba students were also recruited by the CIC for the project, working on material properties research and the modelling and analysis of the door (Appendix 2).

b. Outputs

Building the capacity of the team members of the CIC

The project was a great learning opportunity for the two summer students, Mr. Komus and Mr. Moffat from University of Manitoba's School of Engineering. While working on the project, they had the opportunity to gain exposure to resin transfer moulding technology methods and material properties specific to composite materials. Ten years after the completion of the project, Mr. Komus and Mr. Moffat are working at the CIC as a Principal Engineer and as a Mechanical Engineer, respectively.

Advancement of an existing product using innovative technology

Through this project, MCI developed the capability to modify their existing manufacturing technology with the addition of silicon bag resin infusion processes for early prototypes then resin transfer moulding light. The infusion process amalgamated fibreglass reinforcement and resin to improve the quality of the outer surface finish of the door panel. The end product was comparatively more refined and was easier to install than the baggage doors produced using the previous manufacturing process.

Technology transfer of a new resin system

For this project, the CIC and MCI teams, in conjunction with Polynt (formerly the CCP Composites), implemented a new resin system which produces baggage doors with superior properties compared to the previous doors. Polynt Composites is a global leader of thermoset resins that specializes in the development and production of various composites products such as unsaturated polyester resins, vinyl esters, gel coats, and derivatives.[55] The door had to undergo finite element analysis (FEA) to ensure that the door can operate in different environmental conditions.[56] "Due to erratic weather conditions in Manitoba, the MCI coaches often have to drive in temperatures ranging from -40F to 140F in a day," said Mr. Mark Townsley.[57] Therefore, it is essential to assemble quality products for the coaches which can withstand the extreme conditions. With this innovative resin system, there was a strong seal between the body and the door of the buses, making the MCI baggage door less vulnerable to water leaks and internal corrosion.

c. Outcomes

Drop in manufacturing cost

The team successfully reduced the manufacturing cost of each baggage door by 30%, compared to that of the previously manufactured door.[58]

Weight reduction of the baggage door

Another key deliverable during the development of the product was to reduce the weight of the traditional doors. In order to tackle this issue, the team focused on developing a baggage door with the inclusion of composites which made the doors lighter. By the end of the project, there was a weight reduction of 30% per door.[59]

Knowledge transfer to the Ground Vehicles sector in Manitoba

The new door came out of the mould in a near-perfect shape, due to the application of the resin system and the RTM Light moulding process, resulting in reduced installation time. Many bus manufacturers like New Flyer and other major tractor producers in Manitoba also started to use this technology in almost 80% of their vehicles.[60] RTM Light[61] and sandwich construction[62] are techniques that are used by manufacturers to produce lighter doors worldwide.

Establishment of new connections for the CIC

The relationship that was developed between MCI and the CIC provided a pathway for future collaborations. After the completion of the project, the CIC and MCI worked together on numerous projects such as sidewall development, structural analysis of frontload caps, side service doors, rear engine doors, exterior panel projects, and others.

Figure 4. The baggage door produced by Motor Coach Industries[63]

Broader economic impact on the economy of Manitoba and the company

MCI now manufactures a greater number of high-quality baggage doors for buses. The inclusion of a lighter baggage door to their coaches stimulated demand and was an important factor in increasing MCI's manufacturing capacity to more than 25,000 doors since the completion of the project.[64] The resulting increment in sales contributed to the job sustainability rate in the province. "MCI sells more buses then the people working with MCI can sustain their jobs, so the impact is profound," said Mr. Townsley.

d. Challenges faced while working on the baggage door for MCI

According to Mr. Townsley the most challenging part of the project was to finish the work within the specified timeline. Due to the attractive features of the product, there was always a push from the company to truncate the timeline, so that the new and improved door can be launched as early as possible. Besides this, other technical issues like ensuring that the doors were robust and kept its shape after it came out of the moulding process, ensuring that attachment points were designed adequately enough to resist the forces of the vehicles when opening and closing it were comparatively easier to tackle by the team. "The CIC was paramount in the initial design and structure of the door," said Mr. Townsley.[65] "Their efforts, excellence, and tackling the challenges that came their way made the team complete the project smoothly."

4. Sande Curling Innovations Curling Broom and Brush Head Projects

Located in Winnipeg, Sande Curling Innovations (SCI) is committed to developing new techniques and ideas through consulting with athletes, stakeholders and equipment manufacturers related to the sport of curling. SCI focuses on applying various scientific disciplines and techniques to advance the sport of curling.[66]

The idea for the curling broom and brush head projects came out of an informal discussion between Ms. Lindsay Hunter, a previous employee of the CIC and the co-owner of SCI, Mrs. Jennifer Sande. While attending a Master in Business Administration (MBA) class together, Mrs. Sande discussed the idea of constructing new curling brooms and heads to make curling more enjoyable and at the same time reduce the physical strain on players. Ms. Hunter suggested that SCI approach the CIC and after several discussions, SCI and the CIC formally started the project in April 2013.

In the curling community, current broom designs had poor ergonomic functionality, which led to the idea to change the handle design. SCI envisioned a new generation double-handled broom, which would help the player to exert constant pressure while sweeping therefore allowing for more control of the rock. SCI first approached the CIC with a prototype made of aluminum and later developed the design for the "Xtreme Force Curling Broom/Handle." In addition to the handle, SCI also wanted to reinvent the traditional brush head. Using a pressure sensor created by SCI, it was observed that the pressure exerted by a curling player on the brush head was mostly concentrated in the centre, which meant that force applied by the curlers was applied to a small area of the ice surface. To remedy this, SCI and the CIC began developing a new brush head where the pressure is evenly distributed.

During the first phase of the development for the broom, foam prototypes were built, and then given to professional curlers for testing; this included elite teams that helped to choose new design features like position of the hand grips along the length of the broom and size of the finger grips on the handle. The next stage of development was to identify the right type of material for the handle. The handles were rapid prototyped at the Industrial Technology Centre and then tested at the CIC. During testing, various forces were applied to the prototypes to determine the breaking points. After testing several materials, the team decided to build the handles out of carbon fibre prepregs (i.e. an FRP reinforcement that is pre-impregnated with a resin).[67] The original plan was to construct the broom out of fibreglass reinforced thermoplastics, but the design was eventually changed due to manufacturing constraints.

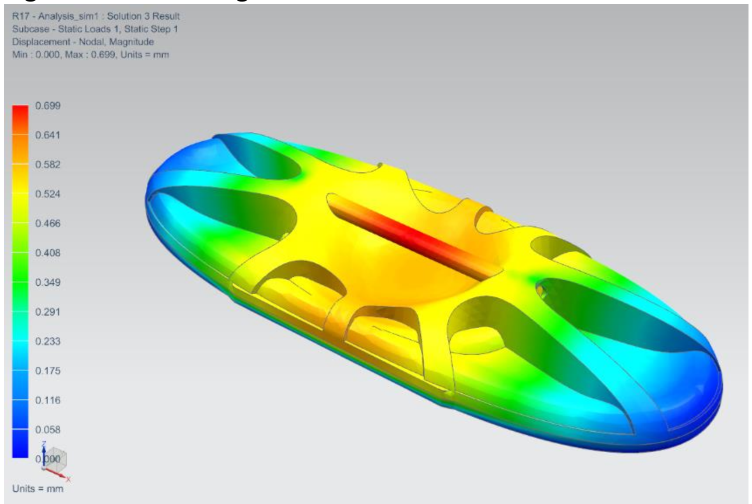
The brush head project was executed in various phases. They first phase utilized data from the brush head sensor developed by SCI to map out the distribution of the pressure from the head on the ice surface. These identified regions where the pressure is high or low and using this, the CIC team could successfully design a head that evenly distributed the pressure.

The team initially designed 2D models to identify different features of the brush head that will help to evenly distribute the load on the ice. The CIC then modelled the brush head and it was analyzed by breaking it into components for accurate representations on the pressure map. After several iterations of testing on the 3D model, the team finalized a design and moved forward with prototyping. With the help of rapid prototyping,[68] the first plastic prototype was developed and tested. Even though the pressure distribution was ideal, sliding the prototype smoothly over the ice proved difficult when a curler was using the broom for balance while throwing a rock. To fix this, the team changed the design by inserting a flat spot on the front surface of the brush head.

Subsequently, other minor changes were also incorporated, such as the addition of clips so that the foam attachment can be removed and attached quickly. To support the foam padding development for the head, the CIC worked with Daher Manufacturing, a firm based in Winnipeg that specializes in moulded foam products. With the addition of the clip system, the foam paddings can be easily replaced without the need to replace the entire brush head. One of the advantages of the new pad is that the fabric is co-moulded with the foam pad. This eliminates the need for multiple staples and makes for a nicer seam edge.

At the end of the project SCI expressed their positive opinions on working with CIC saying, "The staff at the Composites Innovation Centre have been helping us with the design, materials and testing of a revolutionary curling brush. Our collaboration has been extremely productive because of their hard work, knowledge, ingenuity and dedication. We look forward to working with them on future projects."[69]

Figure 5. Initial design of the broom head[70]



a. Inputs: funding and people

The formal contract for the development of the curling broom head was divided into two parts; one for the prototyping and the other for the design of the curling head. The total funding needed for the design of the brush head was $13,000 and for the prototyping, the total funding was $11,000. For the broom handle, the total cost of the project was $10,000. Apart from the funding mentioned above, there were additional investments made by SCI once the product went into manufacturing.

Five members from the CIC worked on the broom hand and brush head projects. The timeline for the broom handle project was from April to October 2013, while the brush head project was from December 2014 to May 2016. The team's contribution focused on CAD modelling, prototyping and conducting stress analysis testing in the lab (Appendix 2).

b. Outputs

Advancing knowledge of the staff members of the CIC

For the brush head project, the CIC had to use an innovative methodology called rapid prototyping. This method helped to differentiate between effective and ineffective design options.[71] Overall the project helped to advance learning of the team members by introducing them to newer technologies.[72]

Informing the CIC's work

Although the work undertaken by the company for this project was not officially documented, the findings were shared and applied by SCI and the CIC. For instance, the CIC is currently using rapid prototyping methodology to produce production aids for the manufacturing of prototype tooling for an industrial ground vehicles client.[73]

Collaboration among Canadian manufacturers

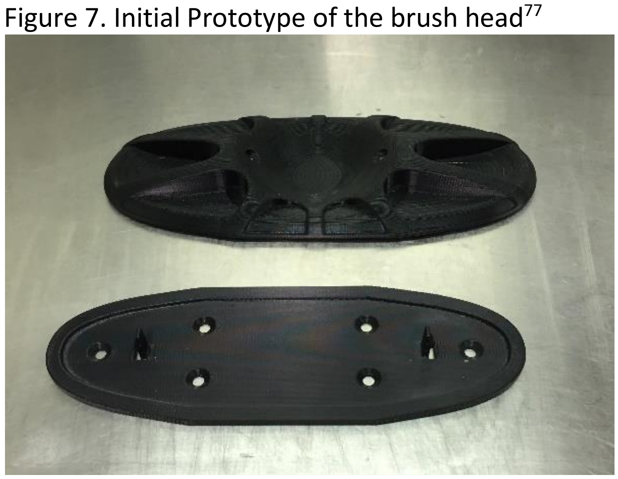
Since the product is built using components manufactured by different companies, it reflects the importance of collaboration between different Canadian companies. The handle is produced by Asham Curling Supplies, a company based in Winnipeg and founded in 1978. It started as a supplier of curling equipment such as brooms, handles, footwear and apparel. Today the company is an international name and a leader in the curling industry.[74] Another company involved in the project, Performance Curling, is a design and manufacturing company that operates to meet the needs of curlers. Based in Québec, the company is currently producing the new broom head designed by the CIC. Daher Manufacturing, as previously noted, manufactures the foam pad for the bottom of the brush head. The combined effort of three Canadian manufacturers resulted in products that are marketed worldwide. The manufacture of the broom handle and brush head is therefore helping to sustain many jobs in several Canadian provinces.

Patenting of the design

SCI submitted a patent for the design of the handle and brush head soon after the completion of the project.[75] This is a breakthrough project for SCI, since the new broom and head are innovative in the sport of curling.

Figure 6. Final Design of the brush head[76]

Figure 7. Initial Prototype of the brush head[77]



c. Outcomes

Capacity building of University of Manitoba students

The second generation of the curling broom will be completed soon by the CIC, for which they have recruited several University of Manitoba students to support the project. As a part of a 4th year course, the students from the engineering program have to work in teams to develop a project over four months, starting from the conceptual stage to the final design. Industrial partners are generally approached for project ideas.

Licensing of the products

The new design of the head and the broom has been licensed to two manufacturers: the brush handle was licensed to Asham Curling Supplies, and the brush head to Performance Curling. Currently, the brush head is in pre-production while the broom handle is on hold pending approval from the World Curling Federation.

Commercialization of the new brush head[78]

The broom head is expected to be launched in the market in 2017. The initial production run for the head is 2,000 units and is expected to multiply rapidly after the first year. With this addition to their product line, SCI is hoping to reach out to curlers all over the world.

Reduction in sales cost of the curling broom

This manufacturing-friendly design was cost-effective to make, and is sold at around $40 to $45. The new broom handle is currently sold for $225 whereas the traditional broom's market price was $190.[79] Although SCI's broom handle is more expensive compared to traditional ones, the superior properties compensates for the price.

Improving the broom with more player friendly features

The handle has been in the market for almost a year and it has also managed to gain a lot of positive feedback from users. Curlers found that sweeping is more efficient with the new handle and causes less fatigue as the handles allow the curler to push and pull with the same force.[80] With the new hand grips, curlers can exert 10-20% more power on the push stroke and also exert up to 40% more power on the pull stroke.[81] This means that curlers using the broom are now less susceptible to injuries to their shoulders, wrists and elbows and it also reduces their fatigue as they can apply less pressure on their grip. The new brush head is also comparatively lighter by nearly 60 grams which makes it easier to handle.[82]

d. Challenges faced by the team while working on the Sande Curling Broom and Brush Head projects

Identifying the appropriate method to produce a strong handle

The team had to implement different methods to design a handle strong enough that can withstand the pressure during play, especially at the joints. After several rounds of testing in the laboratory, the final prototype of the broom with the right materials was created. This was the most challenging task for the team according to Mr. Komus, the Project Manager.

Appropriate geometrical dimensions of the brush head
While developing the brush head, one of the major challenges was to identify the right geometrical dimensions. Despite having a distinct goal in mind, the team had to invest a large portion of their time in research to figure out the right geometrical properties. To overcome this challenge, injection moulding was adopted to accommodate the more complex geometry.[83]

PART III: Discussion

1. Impacts and attribution

In identifying and documenting the CIC's impacts, the impact narrative addresses two questions:

- What are the impacts that the CIC has helped bring about in the Manitoba composites and bio composites sectors?
- To what extent has the CIC's collaborations with private companies/partners contributed to its mission/goals?

Using contribution analysis to frame the discussion around these questions, the impacts arising from the CIC's research and other activities are identified and linked by the causative elements/mechanisms (Figure 8). Based on what is known about the CIC and four selected projects, the CIC's theory of change is: that its activities, services and leadership in the composites sector are accomplishing its goal (i.e. support the industry in developing and commercializing current and new composite applications and technologies). The factors that facilitated the change include its leadership, reputation, skilled and experienced staff and active collaborations with industry that started with the CIC's founding and continues at present.

The contribution of the CIC to the composites industry in Manitoba is extensive and can be categorized into three parts: economic, enhancing the capacity in the composites sector, and informing the work of the CIC and its partners.

a. Economic impacts

The CIC's collaborations with various companies in the Ground Vehicles, Aerospace, Industrial Products and Bioproducts sectors has led to an impact on the Manitoba economy including the creation of new jobs and increasing the amount of locally produced products. For instance, the creation of an internal door panel for Rockwell Collins and the Sandvik Eris control panel project led to addition of new jobs in the province. Additionally, the production of the Sande Curling Broom and Brush Head and MCI Baggage Door projects helped to sustain jobs since these innovative products helped the companies to compete and expand production.[84] [85] Furthermore, the CIC's capabilities in design, testing and prototyping has led to the creation of new and/or the improvement of existing products that have been highlighted in the four projects discussed in this report.

The President of the company, Straw Logic, believes that the work of the CIC has been praiseworthy in the biocomposites sector. According to Mr. Joe Hogue, “the capability of the CIC is unique in this area of research which is a crucial factor behind its success and will continue to be so for many more years to come.” [86] “The company has put in tremendous amount of effort in developing the value chain of the economy,” he adds.[87]

The impact of the CIC’s work on the Ground Vehicles sector is an example of how the company is leading the area of composites industry. For the MCI Baggage Door project, the team introduced MCI to a new process known as resin transfer moulding light (RTM Light) which was also adopted by several major transportation companies for their manufacturing process.

While it is difficult to quantify the return on investment due to limited access to financial data from the CIC’s industry partners, it is likely that the return on R&D expenditures of the CIC’s clients is significant. For instance, the R&D of SCI’s innovative broom handle and brush head cost $34,000 in total. Similarly, the cost for MCI’s baggage doors amounted to roughly $82,000. As a result, MCI was able to produce lighter doors that were more cost effective and easier to install. The same can be said for Sandvik and Rockwell Collins where the R&D expenses were about $22,000 and $40,000 respectively. The inclusion of composites as an integral material in these products has led to creation of superior characteristics that make them more attractive in the marketplace.

b. Enhancing capacity in the composites sector

The CIC has fulfilled its goal to provide the necessary training that is required to test and implement products utilizing composite materials. Specifically, the CIC has organized workshops on the composite manufacturing process, provided training opportunities for students, and hosted seminars for industry members like Advanced Automation in Aerospace to disseminate the knowledge on composites manufacturing procedures and attract industry partners’ attention to the sector.

The CIC has boosted Manitoba’s capabilities in composites in academia and the private sector. In academia, the CIC has helped mentor students through academic courses, internships or association with student bodies of University of Manitoba. In the private sector, the CIC’s pre-commercialization and commercialization activities have allowed companies to gain capabilities that have increased their manufacturing capacities. In collaborating with the CIC, the capabilities gained by companies have increased sales, created new jobs and enhanced their growth. An example is the work with MCI where the application of the RTM Light technology has directly helped MCI. Within its own ranks, the CIC also builds its capabilities. Processes like rapid prototyping, material testing, impact testing and the RTM Light were used by the CIC staff. Mr. Alastair Komus for instance, started as a summer student at the CIC working on the MCI Baggage Door project and then went on to become a permanent employee of the CIC and lead the Sande Curling Broom and Brush Head and Sandvik Eris Control Panel projects.

c. Informing the work of the CIC and partners

While the CIC has produced few peer reviewed publications, the knowledge gained from collaborations with industry partners has informed their own work and that of their partners. For instance, the results from the impact testing from the Sandvik Eris Control Panel project has been used in other projects. Knowledge resulting from projects have also informed the training of the CIC and industry staff, as well as interns and summer students from the University of Manitoba. The CIC works in the Aerospace, Ground Vehicles, Industrial Products, and Biomaterials sectors offering a wide range of services including product development, material and process, composite design and analysis, testing, tooling, and prototyping capabilities.

The CIC's reputation for advanced experience in the composites sector is continually attracting new clients. In the projects presented in this narrative, formal agreements were entered into by the CIC and its industry clients, defining the roles, the scope and cost of the project, as well as the timeline. Industry CEOs and other participants have attested to the critical role that the CIC has played in the growth of their companies.

<u>The CIC's collaborations with the private sector contributes to its mission/goals</u>

Since its inception, the CIC has worked towards accelerating the growth of the composite manufacturing industry by supporting the industry in developing and commercializing current and new composite applications and technologies and attracting new industry partners and startup companies in the sector.[88]

The CIC supports industry by offering value-added services and also supports training and information sessions. The workshops organized by the CIC has attracted leaders from different arenas to share ideas and knowledge and also increased the volume of information flow within the industry.

As solution providers, the CIC works with its industry clients to develop unique products or improve existing ones. The CIC always designs with the manufacturing process in mind taking into consideration material selection, design and manufacturing process. While most of these activities are implemented with the knowledge previously gained from completed projects, others are a result of a completely new and innovative work. Through these major activities, the company helps eliminate technology gaps and assists the industry with achieving their goals.

As of 2016, 13 years after its founding, the CIC has assisted the industry by working on 516 projects, transferring 146 technologies to the industry, working with over 167 industry partners and established 57 new capabilities with clients. Currently, the company invests its resources in approximately 15 to 20 technology transfer projects a year, which aids in the growth of the province's economy and helps in job creation.

In over a decade, the company has been affiliated with various private and public stakeholders. Through its work, the CIC has helped to transfer cost-effective and efficient manufacturing processes and materials to its industry partners. The bulk of their work involves further advancement of existing market products. This is done by integrating composites, such as for the control panel for mining operations for Sandvik and the baggage doors for MCI. As a result of working with the CIC, these companies together with Rockwell Collins and SCI, have improved products that are innovative, cost-efficient and maintain a high standard of quality.

In the biocomposites industry, the CIC has helped bring about revolutionary advancements through their work with stakeholders and industry. “Some of the CIC’s engagement with provincial and federal governments relating to policy development has directly contributed to the development of industries that source bioproducts as raw materials,” according to Mr. McKay. For example, the CIC participated with several other not-for-profit organizations, industry, academia and government to develop Growing Green, the Manitoba Bioproducts Strategy. The Strategy supports the creation of a bioproducts industry using agricultural biomass. The CIC also led a program entitled BioNet Manitoba which facilitated the growth of bioproducts supply chains by drawing the attention of the industry, producers and government.[89]

The CIC as an attractor

The CIC attracts companies in composites through its leadership, close association with industry and support its clients with new capabilities. For instance, the CIC was approached by Sandvik after an employee had previously met Mark Townsley. Besides introducing Sandvik to composites, the collaborative work led to an improved product for Sandvik and the CIC’s experience in impact testing was later utilized in other projects.

The CIC’s close association with industry goes back to its establishment. In fact, the founding of the company was supported by stakeholders and was meant to serve as a technology centre, provide skills and training and bring in investment capital. The CIC’s sustained delivery in these three areas has attracted the continuous participation of other companies and contributed to its growth.

In the biocomposites industry, the CIC has provided support to the emerging companies and helped ease their path towards success. Erosion Control Blanket is one such company that started its operations in Manitoba in 2001 as an importer and marketer of flax non-woven products.[90] Mr. Mark Myrowich, CEO, said, “The engineering and technical support the CIC has, along with their years of research has given us the confidence to enter the natural fibre composite industry that adds value to the abundant ag-fibre resources in Manitoba. Without the knowledge and support of the CIC as a resource, we would not feel comfortable moving into this new industry.”[91]

Mr. Joe Hogue, President of Straw Logic, a company located in Manitoba that provides consulting services on sustainable agricultural biomaterial and biomass advocacy, also shared his positive experience on working with the CIC.[92] Straw Logic is very satisfied after collaborating with the CIC to develop hemp and flax materials for parts of electric vehicles. Mr. Hogue is a big supporter of the CIC and believes that the CIC’s support to industry is essential and that CIC is leading the development of the biomaterials sector across Canada.[93]

The company attracts the participation of various stakeholders and industry partners through workshops, seminars and consortiums. The workshops and seminars conducted by the CIC also help to disseminate important information about the value of composites, which encourages several stakeholders to use composites in their products. In academia, the CIC actively employs summer students and helps to attract and retain the brightest in the region.

2. Knowledge translation and impacts

Knowledge translation (KT) is defined by CIHR as a “dynamic and iterative process that includes synthesis, dissemination, exchange, and ethically-sound application of knowledge to improve the quality of life of Canadians and provide more effective services and products and strengthen the health care system”. CIHR makes a distinction between integrated knowledge translation (iKT) and end of grant knowledge translation. In iKT, key stakeholders/intended knowledge users are included during some portion or all of the research process. End of grant KT on the other hand, are activities “aimed at diffusing, disseminating or applying the results of a research project”.[94] For the purposes of this document, KT is the umbrella term for all activities involved in moving research from the research space (e.g. laboratory) into the hands of people, groups, and organizations who can put it to practical use, eventually leading to impacts. KT is not an action, but a spectrum of activities that change according to the type of research (i.e. pure or applied), the funds/time allotted for disseminating research findings, and the audience being targeted.

Understanding and optimizing how research is translated is critical to identifying and improving the outcomes that arise from research – including commercialization activities and broad social, environmental, and economic benefits to Manitoba and those that are non-commercial in nature such as behavior change interventions, policy changes and the like. Grimshaw et al (2012) notes that one of the most consistent findings in research is its failure to translate into meaningful changes in practice and policy.[95] Billions of dollars are invested every year into research that is meant to address problems and issues facing all facets of modern society. The aim of this section is to determine and analyze the activities that led to the impacts that research done by the CIC has had and contribute in understanding how knowledge translation lead to impacts.

Established in 2003, the CIC supports and stimulates economic growth through innovative research, development and the application of composite materials and technologies for manufacturing industries. With support from industry and Winnipeg and provincial government, the CIC was created as a central organization to help galvanize growth in the Manitoba composites industry. The CIC partners with industry members and help create new or help to further develop composite products and technologies for commercialization. The success of the CIC and composite research in Manitoba have to do with the following factors:

a. Engaging end users and decision makers

Since 2003 the CIC has continuously engaged with key end users and decision makers from the public and private sector within Manitoba and around the world. Internationally, the CIC is collaborating with research institutions and investigators from other countries on biocomposites to support FibreCITY, an initiative that aims to develop the world’s first and foremost biofibre grading database. Locally, the CIC has worked closely with CEOs and managers from Manitoba companies including MCI, Rockwell Collins, and Boeing. As of 2016, the CIC has facilitated 146 technology transfers, which are important activities since they provide value to the partnership between industry and research. One example of the benefits of technology transfer projects is when the CIC brought together the MCI teams, in conjunction with Polynt (formerly the CCP Composites) to create a new, lightweight baggage door for buses that can withstand the extreme temperature variances in Manitoba. This project helped to reduce the weight of commercial busses to reduce fuel consumption utilizing environmentally friendly manufacturing practices and materials. The value-added activity helps to form the basis for continued partnerships as well as informing future research activities. However, these partnerships would not be possible without effective engagement by the CIC with industry members. To establish and maintain meaningful partnerships with key external stakeholders the CIC organizes workshops/seminars that provide a space for key stakeholders and industry members to share ideas, knowledge, and needs/capabilities with one another. Additionally, the CIC regularly attends conferences, tradeshows, and similar events to establish relationships and sustain the organization's knowledge about the local, national, and international composite industry.

b. Building capacity

The CIC has taken a holistic approach to building capacity in composites by training students as well as industry practitioners. In general, implementing an innovative approach or product is a challenge that requires conceptual and practical training to ensure uptake. Consequently, the CIC has sponsored a training program for private sector stakeholders about the value of integrating composites into their products, and another program titled the 'technician training program' for practical training of composite materials. These training programs are necessary to help galvanize interest in utilizing/implementing composite materials from industry members. Additionally, the CIC works with industry partners on projects that provide practical experience for industry and academic participants. Over the past 14 years, the CIC has worked with 150 industry partners on 516 projects, that collectively provide the foundation for the continued development of the composite industry in Manitoba.

c. Leadership

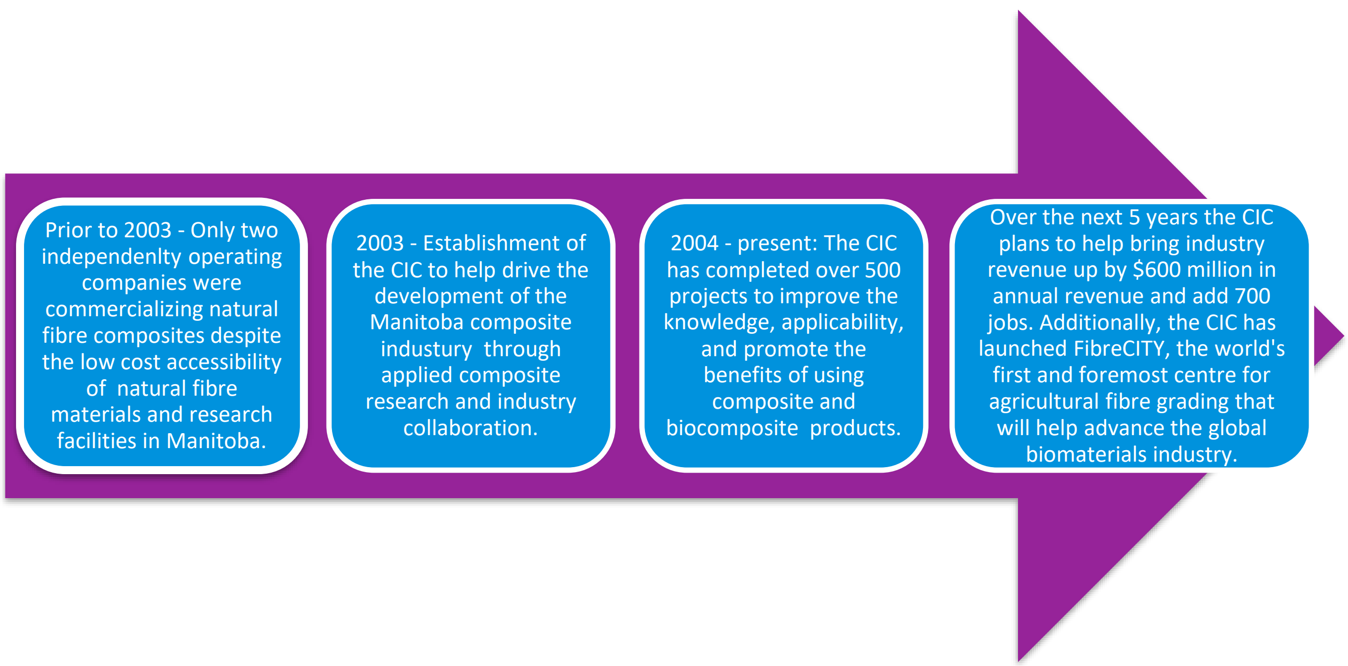
The composite sector in Manitoba has made significant strides with the CIC acting as a development centre and network hub in Manitoba for composite technologies and applications. The CIC has been able to facilitate the creation of new products and help improve existing ones to meet the demand for more cost effective, durable, and lighter materials from industry. With a commitment to applied research as well as in-depth knowledge of industry members/organizations, the CIC has been able to facilitate hundreds of projects to date. These collaborations provide hands-on experience with composite materials that in-turn helps to develop the capacity of Manitoba businesses. As a result of the activities facilitated by the CIC, Manitoba's composites industry has become a leader nationally and internationally as well as contributed to the Manitoba economic development.

Leadership is instrumental to ensure the uptake of innovative products/services or to establish a new industry. As a relatively new industry, the CIC has been instrumental in providing the expertise required by industry partners to create and develop biocomposites products. One important development in the Manitoba biocomposites industry is the establishment of FibreCITY, an initiative of the CIC to help grade the materials utilized in biocomposites. By establishing a grading system, the biocomposites industry in Manitoba will be the world's first to establish a database to systematically and effectively identify structurally reliable materials to be utilized in biocomposite products.

3. Time to impacts

Prior to the founding of the CIC in 2003, there were only two biocomposite companies operating independently of one another. However, due to the applied research that the CIC undertakes in developing and commercializing composite applications and technologies, the creation of impacts has been quick. For instance, about 15 to 20 technology transfers to industry take place each year. By 2016, the CIC has facilitated with over 500 applied composite projects and transferred 146 technologies. These outcomes are from partnerships/collaborations between the CIC and industry members in Manitoba, which have continued to grow, building on previous successful collaborations. Additionally, the practical nature of these projects has provided great learning opportunities for academic and industry members in Manitoba that have resulted in an increased capacity to provide innovative, composite products locally. Presently, there is a growing shift towards biocomposites that Manitoba is well positioned to capitalize on nationally and internationally due to the success of the CIC.

Figure 8: Time to impacts



4. Future of composites and biocomposites for the CIC and Manitoba

Manitoba and Western Canada is well known as a hub for technological advancement in composites. The CIC is hoping to further stimulate this growth by expanding their skilled labor force and adding diversified services to their capabilities. To turn its vision into reality, the CIC is building extensive networks and forming numerous consortia.

According to Simon Potter, former Vice President, Product Innovation, CIC, "Manitoba has a real opportunity to be a global biomaterial centre."[96] Supporting his claim, Mr. Rick Jensen said that, "the future for biocomposites in Manitoba is very bright. As the world seeks to meet targets for reduction of greenhouse gas emissions, manufacturers will be looking for materials that make products lighter, especially for transportation vehicles."[97]

Among its diversified list of innovative projects, the Green Garage is a notable one as it is made entirely of sustainable components. Situated at The Alternative Village in University of Manitoba, a unique research hub established over one and a half acres of land that serves as a venue for research, testing and industry partnerships, the project displays the usage of ag-fibre biocomposites as alternative building materials.[98] The purpose of this project is to exemplify how green building materials can be applied in Manitoba and also all over Canada.[99] Another biocomposites project that CIC has initiated is FibreCITY, the world's first and foremost centre of excellence for agricultural fibre grading. With FibreCITY the CIC plans to "set the standards for the new bio economy, not only in Canada but throughout the world, build next generation of vehicles, buildings and consumer products and form a unique network of technologies and experts to advance the global biomaterials industry."[100]

Several factors will play a positive role in the CIC's future and the future of the composites sector. First, Canada has strong aerospace and ground vehicles sectors. Canada ranks fifth in world aerospace sales and employment, and third in civil aircraft production. [101] "In terms of the composites sector's impact to Canada, I think the country has the opportunity to be a world leader in this field," said Mr. Rick Jensen. However, in order to reach the pinnacle of success, Mr. Jensen believes that the industry needs abundant research on composites as well as biocomposites and continuous support. "The work the CIC is undertaking can set the foundation for the wide use of these materials. All that is needed is the continued support that this research requires and the desire by Canada to be the leader in this field, no pun intended," stated Mr. Jensen. [102]

Second, the usage of composites for the body of aircrafts, mostly for civilian and military aircraft production, is increasing, from nearly zero to 55% between 1975 and 2015.[103] In the ground vehicles sector, the use of composites has risen due to the presence of various prominent manufacturers like MCI, New Flyer Industries, Westward Industries, Buhler Tractors and Triple E Recreational Vehicles. Lastly, some of the CIC's clients like Sandvik and Asham Curling Supplies (the company that sells the licensed curling broom of SCI) have stores located in countries like Switzerland, Germany, the United States etc. Their wider market reach will benefit Manitoba and Canada, and potentially take advantage of existing trade agreements and export opportunities.[104]

The CIC continues to face challenges since its founding in 2003 that have implications to its future, according to Mr. Sean McKay, the CIC's CEO. Some of these are:[105]

- The biggest challenge that still exists today is developing a sufficient long-term flow of funding which can support the CIC to meet the needs of the industry. The changes introduced by political cycles impacts the flow of funding from the provincial and federal governments.
- Obtaining the right level of experience within the organization to be able to best support the industry is another challenge faced by the CIC. To tackle this, the CIC has employed strategic hiring procedures like internships to recruit their staff.
- Developing an idea then taking it to the commercialization stage can be arduous for a composites organization like the CIC that is engaging in a developing biomaterials sector. Understanding the real issues and then filling in the gaps appropriately is somewhat considered to be a challenging task for the company.
- Industry cycles often affect the volume of work of the CIC across sectors. For instance, when the work with the Aerospace sector expands, the CIC's work adjusts correspondingly. A similar approach is taken for the Ground Vehicles and other sectors. However, the CIC's diversified portfolio of services reduces its dependency on one sector alone, which is why the company can seamlessly adapt to the changing cycles.

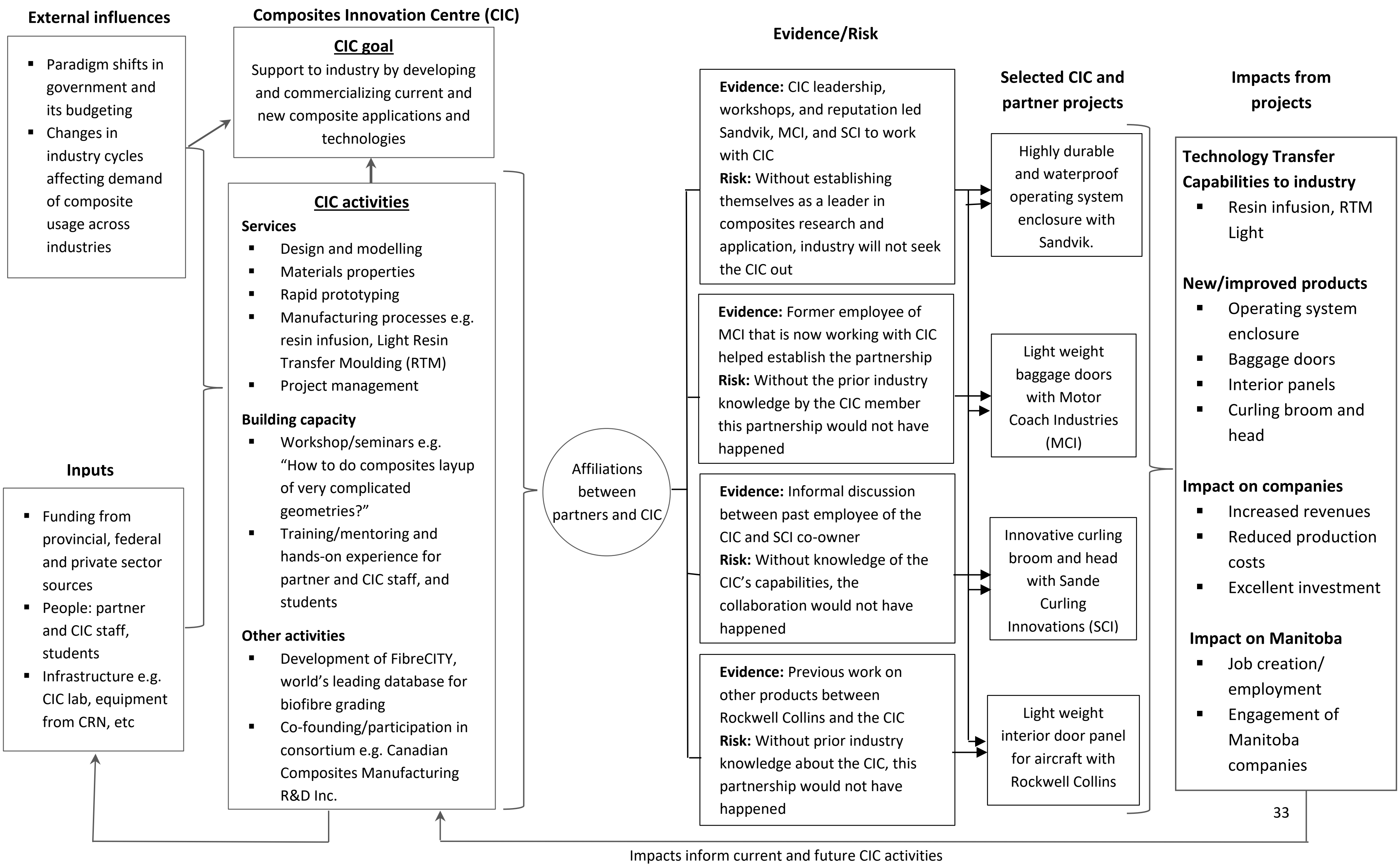
As the composite and biocomposites industries are expanding with time, Mr. McKay also envisages a profitable future for these industries. "Over the last number of years there has been a steady increase in the adoption of composite materials globally aimed at improved performance and weight reduction especially in the aerospace and automotive industries. Reduced emissions have been a major driver. With Manitoba being the home of Canada's largest aerospace composite product manufacturers and North America's largest bus and agricultural equipment manufacturers, this provides for a significant industry pull for these materials in the region. With light weighting of these large vehicles being a priority area, as defined by a recent Vehicle Technology Centre survey, this will only expand the innovative use of composites in these structures," said Mr. McKay.[106] Agreeing to Mr. McKay's statement, Mr. Rick Jensen further added that, "in terms of the future for the CIC, I believe it's just coming into its best years. Over the past 13 years it has matured its business processes and developed strong relationships not only locally but globally as well. As countries around the world look to more environmentally responsible practices in the future, the CIC has embarked on exploring methods of using bio-materials in composite industrial applications. Additionally, there have been several companies that have not had previous experience with composite materials that are now adopting them in their products; for example, grain handling equipment and material transportation systems." [107]

The future of biocomposites also looks promising since, "agricultural crop fibres and bio resin systems are currently being developed from locally grown crops and are starting to see their way into the market place. Considering these initiatives and successes that have been stimulated through support from the Composites Innovation Centre and an emphasis on clean technologies being promoted by our new government leaders, a bright future is predicted for Manitoba's biocomposites cluster."[108] In the future, the CIC, with help from Agriculture and Agri-Food Canada will invest more time and resources in research on fibres from locally grown crops, identify the technological barriers that the industry currently faces and discover effective solutions to facilitate the commercialization of the Canadian biomass, by increasing its usage in the composites industries.[109]

Part IV: Conclusion

After nearly 13 years in operation, the CIC has established itself as one of the leading solution providers in the composite and biocomposite industries. Throughout Canada, the company is well-known for its high-quality services, continuous effort and commitment to create awareness on the benefits of using composites. Through its pre-commercialization and commercialization activities, the company has impacted various industries like aerospace, mining, curling sports equipment and ground vehicles as well as academia. Regardless of size, all the industry clients that the CIC has engaged with agree that the CIC's work has benefited them. The four projects highlighted in this narrative show the pace of advancement in the composites sector spearheaded by the CIC and its impact on the Manitoban and Canadian economy

Figure 8. CIC theory of change: CIC's activities and leadership in the composites sector has produced many impacts and is accomplishing its goal



Appendix 1. Interview Questionnaire for the Impact Narrative

Questions	Data needs
Background	
About the composite industry in Manitoba	**Background of biocomposite industry**
At the time CIC was established, what was the status of the biocomposite industry in Manitoba?	Size of industry when CIC started: revenues, # employed, # of private companies
	Size of the industry at present: revenues, # employed, # of companies
About CIC	**Why CIC established**
1. Why was CIC established?	Rationale for establishment of CIC
2. How did CIC start?	List/description of initial projects, the initial funding amount by source
	Role of CIC in the industry in the beginning
	Role of CIC at present; any changes?
3. Is Manitoba the pioneer and leader in this field of research?	Description of how CIC become a leader in this area of research
Research and impacts	
Based on the diagram sent previously, data would be needed for each section in that diagram: inputs, knowledge translation, and impacts (TTS, other companies/other products, Licensing in Australia and North America, New Flyer Manitoba, Boeing Canada, Traditional composite technology transfers, other technology transfers)	
About the impacts and the associated projects	
1. Are there specific research projects associated with each of the impact above?	List of research projects associated with impacts, type of research e.g. pure, applied
2. How were the projects initiated?	
– Did CIC reach out to the companies or the companies approached CIC?	Description how each project was initiated
– If it was initiated by CIC, what was the motivation behind it?	
– Did the workshops/seminars conducted by CIC play a role in initiating the project?	Role of seminars in initiating projects
3. Is each of the impact a result of a unique research activity or a collaborative one?	List, description of, and contributions to collaborations
4. Please provide the start and end date for each of the research projects.	Start date-end date of each project: the year when research began till the year the product was commercialized/utilized
5. What other composite technology transfer activities/other activities has CIC done?	The type of projects, year it started, progress to date, and economic impacts (e.g. data on investments, sales/revenue, etc.)
Inputs into the projects	
6. What kind of support (funding /infrastructural/technical) was provided by the company/CIC/governmental organizations?	▪ Funding for each project (by year/source/ geographical location) ▪ Research infrastructure: physical, digital, biological/chemical ▪ Other support
7. Who and how many were involved in the project?	People involved

	− # of researchers by location/origin/year, area of research, role in the research
	− # of students by location /origin/year, area of research, role in the project
	− # recruited to Manitoba and # retained
− Did the project(s) make any impact on the career of the researchers/students?	Description of impact on careers/studies
− Are they still working on similar projects in Manitoba or elsewhere (China, Australia, other places)?	Current geographical location, sector, and position of people who were/are involved
8. Besides funding, did any of the projects require governmental assistance?	Type of assistance provided by the government
Outputs/outcomes/impacts	
9. Are there any publications related to any of the projects?	List of peer reviewed publications/citations
	Other publications where the project was mentioned e.g. blogs, newspaper articles etc.
10. Did the research projects lead to an impact on government policies/regulations?	▪ Description of advisory role, participation in discussion, membership in committees/ working groups etc. including how this happened ▪ Citations in government documents (if any) ▪ Description of contribution to any policy change including how it happened
11. Did the research projects lead to any impact on teaching?	Description of contribution to any change/impact on teaching e.g. curriculum change, pedagogy
12. What were the impacts of the projects on these companies, the industry and the Manitoba economy?	Sales figures for commercial products (like curling brooms/tiles/snowboards)
	Product utilization rate (biocomposite doors and motor cases for their planes and rockets)
	Number of jobs created because of the projects (data is required separately for each project)
	Outreach of the projects (national/international level)
13. What are the other impacts of the projects	Data on efficiency, cost-reduction, environmental, and other benefits of the product
14. Are there studies that have measured/quantified these impacts?	Publication/copy of studies (if any) to support the impacts
15. Did these projects (can be any in particular) attract more industry players to invest in biocomposite or shift to biocomposite products?	Number of investors per year and their names, $ value of investments
16. Was any sort of consortium developed through the project?	Name and description of consortium
− How did the consortium help strengthen the role of CIC or create awareness on the project/product?	Role of consortium in industry/CIC; name of the partners involved

	Contribution by each partner: $, value of in kind, people, expertise
	Benefits of consortiums
Additional question on licensing	
1. What kind of license was granted to AgFibre? Was it for a product or a process (or something else)?	Type of license provided to the company, including the date and how it happened
− Is there an intellectual property (IP) for the license?	Description of IP
Additional questions	
1. What were the challenges faced by CIC while working on the projects?	Research related challenges Pre-commercialization and commercialization challenges
2. How do you distinguish between the pre-commercialization and commercialization activities carried out by CIC?	Definition, examples
3. We'd like to obtain the industry's perspective on role that CIC plays. Can you suggest a few persons (CEOs or managers and CIC Board members) that we may contact?	Name and contact information

Appendix 2. The CIC Team members and their roles in various projects

1. Sandvik Eris Control Panel Project

Mark Townsley: As a Vice President, Mr. Townsley helped contribute to the project in designing the Sandvik Eris Control Panel enclosure and also fulfilled the role of an advisor. He still continues to work at the CIC as Vice President, Ground Vehicles and Design.

Alastair Komus: As the Project Manager, Mr. Komus was heavily involved in overseeing, managing and developing the panel from the very beginning. He is a Principal Engineer at the CIC and is currently overseeing other projects.

Angus Cheung: Mr. Cheung was the first engineer to start working on this project. He was recruited as a Junior Engineer by the CIC, and was responsible for the modelling of the control panel enclosure design in Computer Aided Design software (CAD). A large amount of work in the initial stages was handled by Mr. Cheung. This project exposed him to using CAD design software for a real-life application and taught him to thoroughly check the competing technical concerns while developing a product.

Lisa Marmillod: Ms. Marmillod contributed to the project as a Test Engineer. She was involved in the laboratory work during impact testing. She still continues to work for the CIC as an Engineer, primarily in the test lab.

Matthew Lagunera: Mr. Lagunera worked on the design of the enclosure. He is currently working in the Ground Vehicles and Design group at the CIC and additionally provides support to the CIC's lab.

Lynne Kincaid: A student at that time, Ms. Kincaid's involvement was doing impact testing of different material types. Her work helped to select the ideal material for the enclosure. Soon after graduation, Ms. Kincaid joined the CIC as a full-time employee. However, she recently moved to Ottawa to work for another private company but still works with composites.

Natassia Beley: Ms. Beley joined the project as a student to work on the design of the enclosure. Upon graduation, she continues to work for the CIC on a full-time basis.

2. Rockwell Collins Composite Interior Panel Project

<u>The CIC's Team</u>

Steve Crouch: As a Project Manager, Mr. Crouch played a vital role in coordinating resources within the CIC and overseeing the project.

Lynne Kincaid: Ms. Kincaid started working on this project as a summer student. Throughout the course of the project she helped with CAD modelling. She was previously involved in the Sandvik Eris Control Panel project.

Shawna Boyko: Ms. Boyko wrote specifications and quality documents for the Rockwell Collins project. Starting as an engineer in the Aerospace group, she currently holds the position of Principal Engineer in the Product Innovation sector at the CIC.

<u>Rockwell Collins's Team</u>

David Vanderzwaag: Mr. Vanderzwaag's contribution to the project was vital for its success. He joined Rockwell Collins just before the start of the project and was given the responsibility of leading the composite development team. He managed the project, coordinated resources, hired and trained new staff for the project and upgraded the required facilities. Mr. Vanderzwaag still works for Rockwell Collins but his role has changed; he is currently working as the Business Development Manager for the company.

Graham Smerchanski: Mr. Smerchanski was one of the Rockwell Collins engineers involved in the project. As a mechanical design engineer, he designed the panel and assisted the CIC in choosing the right materials. He devised test plans as well as reviewed several technical documents. He continues to work for Rockwell Collins in the same position.

Roshan Siram: As a certification project engineer, Mr. Siram's tasks included effective progression of certification schedules, reviewing designs and drawings, providing support to operation services and more. He is still appointed as a certification project engineer at Rockwell Collins.

Nathan Chartrand: Mr. Chartrand, a student from Red River College (RRC), was hired by Rockwell Collins as a technician for the manufacturing of the interior panel. He has helped in fabrication and testing of the materials at the Rockwell Collins test site.

<u>CRN's Team</u>

Kevin Xiong: As a student, Mr. Xiong assisted the Rockwell Collins team in testing materials and was also involved in various aspects of the project. Mostly, Mr. Xiong provided on-site support performing equipment calibration, helping in layup and bagging trials and evaluation. His input was also essential during first part of manufacturing of the composite door panel.

Dan Lussier: Mr. Lussier, a former employee of CRN, supported the project by coordinating resources between CRN and Rockwell Collins. During the project implementation, the team required several pieces of technical equipment. To address this, Mr. Lussier helped to coordinate the transfer of equipment from CRN to the test site located inside Rockwell Collins. He has digressed from his earlier career path in composites research and is currently working for the Liberal Party of Canada as a Field Technologies Manager.

3. Baggage door for Motor Coach Industries

The CIC's Team

Steve Crouch: As the Project Manager of the project, Mr. Crouch had the responsibility of overseeing the entire project. He played a vital role, from development of the structural design to the processing of the door. Mr. Crouch continues to work for the CIC as a Principal Engineer in the Aerospace, Materials, and Processes sector.

Will Darracott: Working as a senior engineer at the CIC, Mr. Darracott's main role was to help develop the baggage door when it went through processing in the lab. Mr. Darracott is now working as a Principal Engineer, Special Projects.

Sean McKay: Mr. McKay was not involved in the project full-time, but his expertise on the subject matter has provided valuable technical advice to the team.

Two students from the University of Manitoba were hired for the summer term and worked on this project.

Alastair Komus: Mr. Komus was recruited by the CIC as a summer student. He was involved in the material properties research, assisted in the modelling of the light weight door model and conducted analysis on the doors in the design phase. Mr. Komus has become a Principal Engineer for Ground Vehicles and Design sector at the CIC. He was also the Project Manager for two projects in this narrative (i.e. the Sandvik Eris Control Panel and Sande Curling Broom and Brush Head projects).

Steve Moffat: Mr. Moffat joined the CIC in May 2005 as a summer student. Like Mr. Komus, his work focused mainly on material properties research and also on modelling and analysis of the model of the door. He started working full-time for the CIC after graduation and worked for the company for five years. He is now working as a Mechanical Engineer for a private company in California.

Research Manitoba

4. Sande Curling Broom Project

Lynne Kincaid: While Ms. Kincaid's involvement in the project was mostly in CAD modelling, she also invested time on stress analysis.

Matthew Lagunera: Mr. Lagunera helped in developing the prototype of the brush head and the broom.

Andrzej Zaleski: Mr. Zaleski supported the CAD modelling of the brush head and broom as a Technician, Composites Applications at the CIC.

Alastair Komus: As a Project Manager, Mr. Komus provided technical input and also assisted with design and analysis. Previously, he led the Sandvik Eris Control Project.

Eugene Rothwell: Mr. Rothwell is the Vice President, Laboratory, Prototyping and Testing at the CIC. In this project, his main role was to provide technical input and take the lead in the prototyping activities.

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