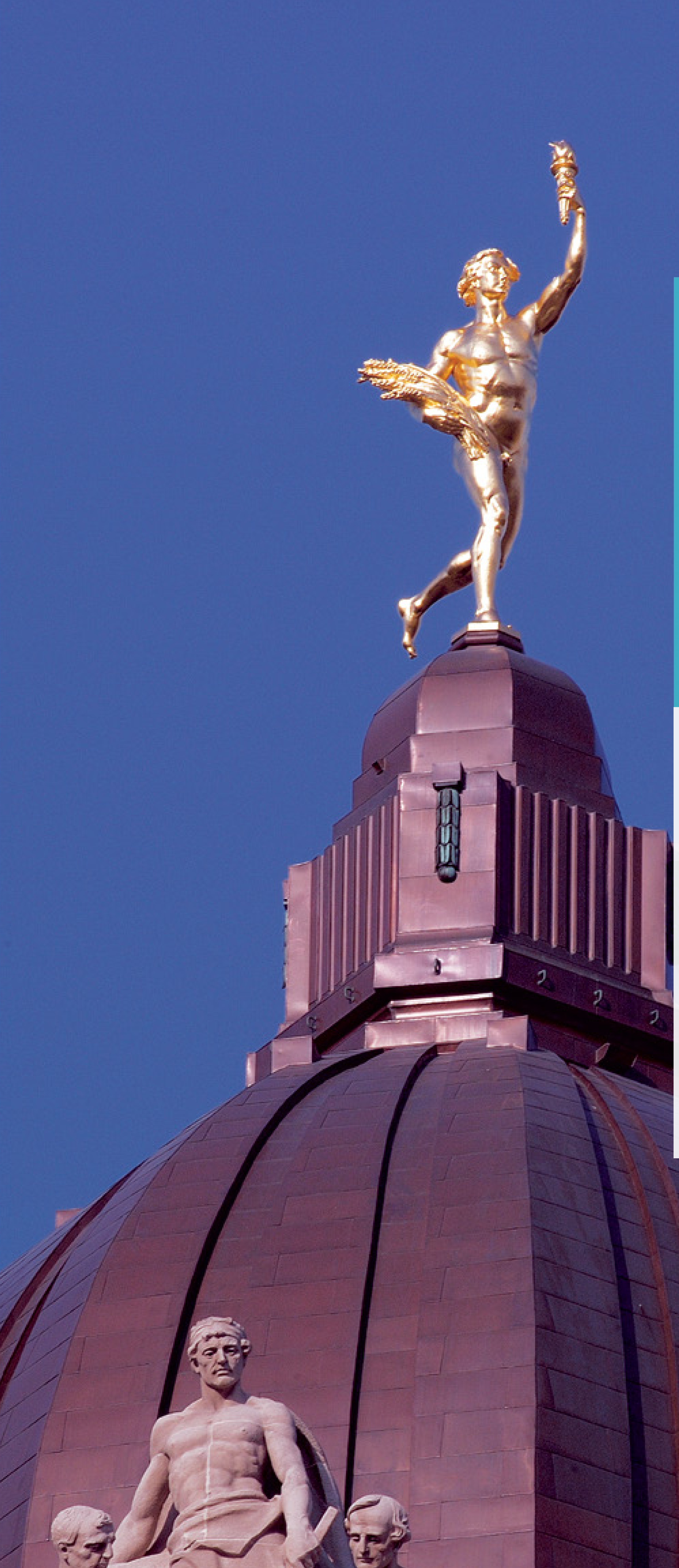
Impact Report //
Fibre Reinforced Polymers & Structural Health Monitoring

Research in Manitoba Accelerates Innovation in the Built World

Research Manitoba



Structural Health Monitoring (SHM)

SHM uses sensor technology to monitor structural integrity. SHM obtains accurate information on the performance of existing infrastructure, determines the health status of civil structures and quickly and accurately identifies structural integrity issues for repairs, throughout the structure's service life. This is the science of Civionics.

When Manitoba's Golden Boy was restored and repaired in 2002, SIMTReC installed sensing technologies to measure the vibrations and strain caused by weather on the Golden Boy and its support column, and the effect of temperature on the material properties of the column. This safety program for the shaft of the Golden Boy, demonstrated that an SHM system could be used to monitor and provide early identification of issues for repair. Structurally, the Golden Boy is now expected to last as long as the Legislative Building.

Fibre Reinforced Polymers (FRPs)

FRPs are a composite material of glass, carbon, or aramid fibres in a matrix of epoxy or vinyl ester resin. FRPs perform better than steel in a corrosive environment, are 75% lighter than steel, non-magnetic, help extend the service life of infrastructure, and are cost-effective.

The 1,560 ft. Paradise Island Bridge East, joining Providence Island to Paradise Island in the Bahamas, was constructed in 1967. Recently, the bridge was recommended to be replaced by an international consulting firm.

After testing by SIMTReC, in collaboration with DELCAN International, the bridge was not only retained, the maximum load allowance increased from 15 to 25 tons.

Research in Manitoba
Accelerates Innovation in the Built World

Maryland Bridge — 1999, Winnipeg

No longer able to carry vehicle weight limit set by the city.
Traditional Options: replace the bridge or reduce load limits, affecting major truck routes.
Solution: Carbon FRP wraps reinforced the existing structure.
Lifespan: still performing well 20 years later.
Cost avoidance: millions of dollars.
Traffic disruption: Zero.

One Manitoba Timber Bridge

Strengthened to accept modern traffic loads
Extended lifespan: Decades.
Repair cost: $120,000.
Replacement cost avoided: $800,000.
Traffic disruption: Zero.
Number of timber bridges in Manitoba alone: 575.

Beddington Trail Bridge

The Beddington Trail Highway Bridge in Calgary is one of the first in Canada to be outfitted with FRP tendons and a system of structurally integrated optical sensors for remote monitoring. The bridge is a two-span, continuous skew bridge of 22.83 and 19.23-metre spans, each consisting of 13 bulb-tee section, precast, prestressed concrete girders. Two different types of FRP tendons were used to pretension six precast concrete girders.

The Tomb of Jesus — Church of the Holy Sepulchre

SMT, a private Canadian company that provides SHM related services, assisted the Greek Patriarchate in the installation of masonry moisture sensors to monitor and report on the wall moisture level of the renovated Tomb of Jesus, Church of the Holy Sepulchre, Jerusalem.

To keep pace with projected growth, the world needs to invest **$3.3 trillion dollars** in economic infrastructure into ports, airports, rail, water, telecom, roads, and power every year from 2016 to 2030.

The gap triples if the additional investment required to meet the new UN Sustainable Development Goals is included.

Current infrastructure design codes and standards lag behind existing research and innovation knowledge that will extend infrastructure lifespan and resilience.

Worldwide, there is dramatic underspending on the maintenance of infrastructure.

In Canada

In 2016, the Canadian Infrastructure Report Card found that reinvestment rates to maintain or repair infrastructure is **inadequate**.

Nearly 60% of our core public infrastructure is owned and maintained by municipal governments with an estimated value of **$1.1 trillion**.

30% of our municipal infrastructure was determined to be in **fair, poor, or very poor condition**. Roads, sidewalks, and bridges are in dire need of repairs compared to other types of infrastructure.

Three decades of deferred maintenance work have created a situation where, if the deterioration is not halted, the associated costs will escalate exponentially.

MATERIALS DEVELOPED IN OTHER REGIONS CANNOT BE EASILY ADOPTED IN MANITOBA DUE TO OUR EXTREME HOT AND COLD CONDITIONS.

575

timber bridges were built in Manitoba prior to 1980 and cannot withstand increasing traffic loads.

$260 million

is needed to replace these aging timber bridges, alone.

Civil engineers are not quick to adopt novel products or technologies because of the consequences of product or process failure e.g. a bridge collapsing.

Often, novel products and technologies in civil engineering take 20 years to go from inception to general adoption. SIMTReC has made ground breaking strides in the development of FRPs and SHM over the past 20 years but some skepticism still exists among public and private sector organizations that are not familiar with these technologies/products, which speaks to the need of SIMTReC to continue its work.

Bridging the Infrastructure Gap

The Canadian revolution has been led by SIMTReC – the Structural Innovation and Monitoring Technologies Resource Centre in Manitoba.

Structural Health Monitoring

By using sensor technology to monitor structural integrity, Structural Health Monitoring (SHM):

- provides accurate information on the performance of existing infrastructure;
- determines the health status of infrastructure; and
- quickly and accurately identifies structural integrity issues for repairs.

This is the basis for SIMTReC's new scientific and engineering field: **Civionics.**

Fibre Reinforced Polymers

Composite material made of glass, carbon, or aramid fibres in a matrix of epoxy or vinyl ester resin, Fibre Reinforced Polymers (FRPs):

- perform better than steel in a corrosive environment;
- are 1/4 the weight of steel;
- are non-magnetic and do not conduct electricity;
- help extend the service life of infrastructure; and
- are cost-effective.

SHM and FRPs together:

- provide accurate structural assessments;
- establish maintenance, repair and replace priorities;
- increase the lifespan of existing infrastructure;
- reduce construction costs;
- reduce maintenance costs;
- reduce public risk;
- reduce environmental impacts;
- increase sustainability and provide greater resilience.

SIMTReC is a globally recognized organization focused on structural, materials, and monitoring innovation. Founded in 1995 as ISIS Canada (Intelligent Sensing for Innovative Structures) a Networks of Centres of Excellence (NCE), the organization has transitioned into a leading Research and Resource Centre providing structural health monitoring technological services and innovations in infrastructure. SIMTReC's track record of transferring the research, technologies, applications and knowledge to industry is groundbreaking. The Centre is dedicated to continued advancement in high-level user-focused research and innovation for construction materials, advanced technologies and structural monitoring using sensors — for buildings, bridge structures, and heavy vehicles and equipment.

SIMTReC Structural Innovation and Monitoring Technologies Resource Centre

Around the world, engineers can now:

1. Monitor the health of existing infrastructure.
2. Extend the life of existing infrastructure.
3. Repair and replace only what is needed, when needed.
4. Build stronger, lighter, longer-lasting, and more environmentally-friendly.
5. Save time and money.
6. Reduce risk and disruption.

The Research:

Research has been the basis for every step in this global revolution:

1. Initial and ongoing basic research required to safely and effectively adapt composites to infrastructure applications and monitoring technology to the structural health of infrastructure;
2. Proof of concept work and demonstration projects;
3. The ongoing development and adaptation of technology to address expanding needs and create new products and services.

Technology Transfer:

SIMTReC's track record of transferring the research, technologies, applications and knowledge to industry is groundbreaking.

- SIMTReC developed and delivered educational modules for professors, students, and practitioners across Canada and internationally on how to apply FRPs and SHM.
- To effectively promote the use of FRPs by private and public-sector officials, SIMTReC established standards for use and guidelines for interpreting the data.
- All education modules were the first of their kind and have supported universities with a civil engineering department to have courses on FRPs and SHM.
- Design manuals were developed and utilized by the engineering field to apply products and/or technologies.

Disruptive Tools and Technologies:

Composites and Polymers have been used in other industries. The disruption is in applying these materials in public infrastructure to confidently replace or enhance the long-trusted and engineer-loved elements of concrete and steel. Lighter, stronger, more resistant to corrosion, longer lasting and more environmentally-friendly, FRPs allow infrastructure providers to do more, better.

Adapting existing sensor technology to public infrastructure revolutionizes the planning, priority-setting, risk management and budgeting that plagues infrastructure managers around the world. Real-time quantifiable insights into the integrity and anticipated lifespan of public infrastructure reduces public risk and supports confident decision-making.

Winnipeg Floodway Bridge Span
(Left Picture)

- *THE UNIQUENESS OF FLOODWAY BRIDGES IS THAT THEY ARE DESIGNED FOR 100-YEAR SERVICE LIFE BY USING THE NEBRASKA UNIVERSITY (NU) PRESTRESSED DEEP CONCRETE GIRDERS AND THE UNIVERSITY OF MANITOBA STEEL FREE DECK (SFD).*
- *THE BRIDGES ARE AESTHETICALLY VERY PLEASING, WHEN OBSERVED FROM THE GROUND.*
- *THE BRIDGE ON THE TRANSCANADA HIGHWAY HAS VERY HEAVY TRAFFIC BOTH IN NUMBERS AND GROSS VEHICLE WEIGHT.*

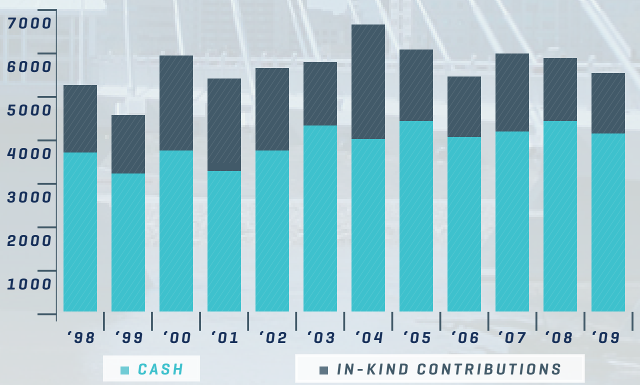
A Great Investment

Revolutionizing a global industry requires investment and support for:

- sound research;
- visionary leadership;
- the development of disruptive tools and technologies;
- system acceptability, in this case, through codes and standards;
- technology transfer from person to person;
- a sound value proposition for decision-makers;
- market access.

From 1998 to 2009, SIMTReC received funding from the Networks of Centres of Excellence (NCE), provincial governments, industry, universities, and other sources, amounting to $48.6 million in funding plus $23.2 million in in-kind contributions.

CASH AND IN-KIND FUNDING RECEIVED BY SIMTReC, 1998-2009 ('000 $)

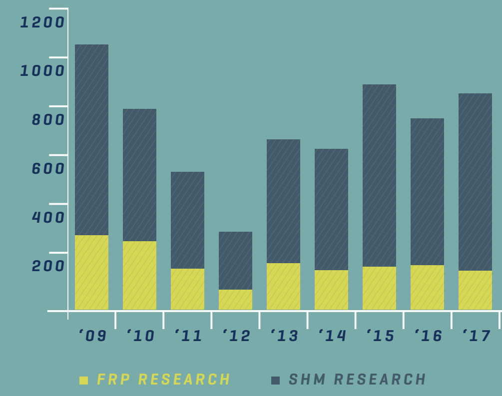


Most Networks of Centres of Excellence close their doors once the NCE funding ends, but from 2009 on, SIMTReC has continued their ground-breaking work finding support through industries, the University of Manitoba, the Province of Manitoba, Natural Sciences and Engineering Research Council (NSERC), and Mitacs.

SIMTReC'S FUNDING BY SOURCE, 2009-2018 ($ '000)

SIMTReC's research funding increased, beginning 2012, reaching $856,740 in 2017. Over the same period, most of the funding has gone to SHM research, averaging 75% of the total with the remaining going to FRP research.

SIMTReC FUNDING BY RESEARCH THEME, 2009-2017 ($ '000)



The Early Returns

Cost savings:

Enhanced information from SHM allows engineers to make tactical and timely decisions on repairing or replacing structures.

Significant repairs or replacements can be eliminated by detecting early defects and preventing them from developing into larger, more costly problems.

SHM and FRP repairs, new design and construction saves billions of dollars in infrastructure costs, extending the life or eliminating the need to replace buildings, bridges, and wharfs across Canada and the U.S.

The opportunities are endless:

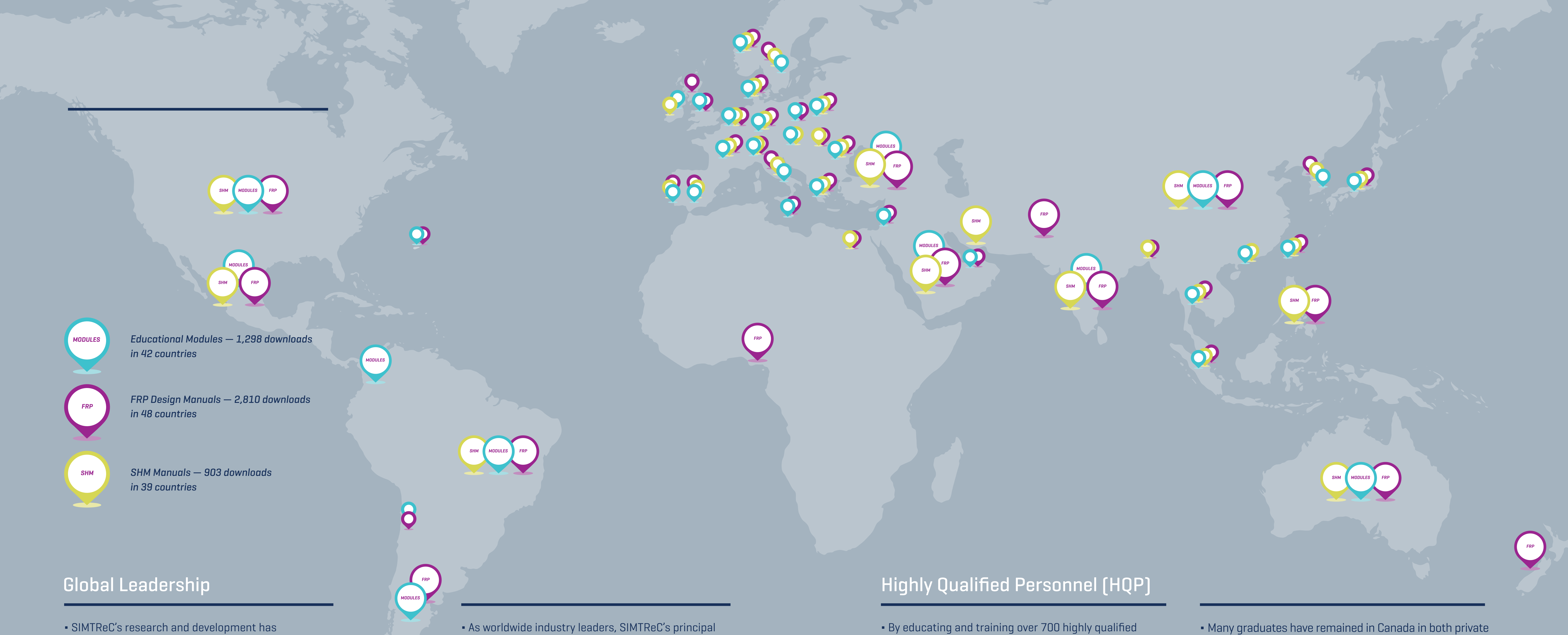
The full potential of FRPs and SHM has yet to be realized. To address this, SIMTReC's future plans incorporate stronger messaging, expanded research, and increased training.

The cost savings not being realized in Canada alone exceed $100 billion.

The Floodway bridges, the Maryland bridge, the Water Pollution Centre roof, and other Manitoba projects have collectively saved Manitoba taxpayers millions.

The Global Revolution

Every country in the world shares infrastructure as a top priority and a major challenge.



Global Leadership

- SIMTReC's research and development has fundamentally shifted the future direction of civil engineering due to its novel work with FRPs and the development of SHM and Civionics.
- Manitoba is well-known internationally as a result of SIMTReC's education modules and design manuals downloaded worldwide.
- As worldwide industry leaders, SIMTReC's principal investigators are invited to present the research and development on FRPs and SHM to government and industry leaders all over the world, every year.
- SIMTReC led the establishment of the International Society for Structural Health Monitoring of Intelligent Infrastructure (ISHMII) and the International Institute for FRP in Construction (IIFC).
- SIMTReC's success is a uniquely Canadian collaborative effort of 30 principal investigators and more than 185 researchers from 14 universities.

Highly Qualified Personnel (HQP)

- By educating and training over 700 highly qualified personnel (HQP) within engineering academia, industry, and government who are now scattered around the world, the benefits of this new technology are being shared directly where and when it is most relevant.
- Many graduates have remained in Canada in both private and public sectors. Among the graduates who are in Canada, 39% are in Manitoba. Many of the graduates are applying their knowledge in the United States, Australia, United Kingdom, Africa, and the Middle East.

Endless Opportunities

PUBLIC SAFETY AND ECONOMIC VALUE

Increasingly, governments in Canada and around the world are adopting cost effective, preventative infrastructure plans that:

- reduce public risk;
- reduce the overall costs of infrastructure maintenance;
- allow for more predictable investment schedules;
- eliminate the need for major repairs, avoiding the associated costs of traffic delays, and social disruptions;
- and increase value for taxpayer investments.

SYSTEM ACCEPTABILITY

For over 20 years, SIMTReC's research and demonstration projects collected evidence for the use of FRPs to rehabilitate and construct new timber and concrete structures. To develop design codes, SIMTReC wrote section 16 in the Canadian Highway Bridge Design Code (CHBDC) in 2000 for the use of FRPs. When it was accepted in 2003, it was the only such design code in the world.

Since then, the Canadian Standards Association (CSA) S806 for the Design and Construction of Building Structures with Fibre-Reinforced Polymers has been integrated in Canada's design codes and has been instrumental for implementation of FRPs in structures other than bridges.

ENGINEERING EVOLUTION

- The Steel Free Bridge deck is widely recognized as the most important development in the design and construction of bridge decks in the last 50 years.
- FRPs are now being used as wraps to strengthen structures such as bridges and as rods for replacing traditional steel reinforcement within concrete.
- FRPs are also effective in different construction and conditions such as cemetery markers, anchorage for post-tensioned masonry structures, structure dowels, and ground anchors.

PRIVATE SECTOR UTILITY

Start-ups and existing companies such as SMT Research, IDERS, FOX-TEK, Intelligent Structures Corporation, and Vector are growing our Canadian economy using FRP and SHM-related technologies that have come out of SIMTReC's research and development activities.

The SMT Research Story :

Founded in 2006, SMT Research designs software and electronics used to monitor and evaluate the integrity and performance of commercial and residential buildings. SMT is at the forefront in developing sensor detection systems that allow for predictive analysis of problems in buildings that may be quickly and economically repaired.

For example, the green roof of the new Red River College Skilled Trade and Technology Centre in Winnipeg now has moisture and heat sensors, and drone technologies to autonomously gather data and inspect the building.

SMT has helped address the leaky-windows crisis, and facilitated the construction of the tallest wood building in the world at University of British Columbia in Vancouver.

SMT is helping develop an augmented reality system with the University of Manitoba Human Computing Interface lab that allows users to inspect sensor data on a building component using a smartphone camera. By downloading an application, individuals can see the pipes, wires, and sensors in the walls of a building through the camera.

Creating Our Future

SIMTReC continues to be Canada's leading and most influential resource centre for structural materials, monitoring, and Civionics research and innovation for buildings, bridges, and heavy vehicles and equipment.

The Centre's five-year plan, building on its solid track record and core expertise, addresses the economic, innovation, and training needs of an expanding community. Specifically, it will:

- Apply SIMTReC's resulting technologies to relevant industries for the benefit of the end-user community and the Canadian economy;
- Be the research and innovation link between the engineering faculty and industry needs and demands;
- Position SIMTReC as a Centre of user-focused innovation;
- Train highly qualified individuals in the transfer of technology to industry and end-users;
- Provide a pipeline of talent that will facilitate the staffing and growth of Canadian companies and Government organizations.

"I see in a 10-year span we will be able to integrate more SHM in materials and we can see a better turn around on efficiency for our construction and the money savings for our infrastructure in general."

— Gamal Mustapha

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